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THE JOURNAL OF WILDLIFE MANAGEMENT

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# AN AMERICAN VISITOR'S IMPRESSIONS OF SCANDINAVIAN WATERFOWL PROBLEMS[1]

*Paul L. Errington*
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In the course of 11 months recently (1958–59) spent in northern Europe (mostly in Sweden), I learned what I could about the conservation biology of Scandinavian waterfowl.

Although my European program was not by any means devoted exclusively to waterfowl, I was able to visit representative wintering areas, migratory routes, and nesting grounds in and near the Scandinavian Peninsula. Most important of all, I had exceptional opportunities for talking with, and often accompanying on field trips, many ornithologists and game biologists working with waterfowl. For background, I consulted an extensive literature, amounting to hundreds of titles, predominantly of Danish, Swedish, and Finnish authors; but, of these titles, only a relatively few are listed in the bibliography.

For their contributions to my understanding of northern European waterfowl problems, I feel particularly indebted to the following: Geoffrey Matthews and other personnel of the Wildfowl Trust, Slimbridge, England; Göran Bergman and Lars von Haartman of Helsinki University; Yngvar Hagen of the Norwegian State Game Research, Vollebekk, Norway; Knud Paludan of the Game Biology Station at Kalø, Denmark; and, in Sweden, Erik Dahl, Gunnar Markgren, and Sam Erlinge of Lund University, Wilhelm Rodhe and Vidar Marcström of Uppsala University, Eric Fabricius of the University of Stockholm, Per Olof Swanberg of Skara, Bo Österlöf of Uddeholm, Gunnar Svärdson of the Institute of Fresh Water Research at Drottningholm, Nils Höglund of the Boda Game Research Station near Söderhamn, and Kai Curry–Lindahl of the Northern Museum at Stockholm.

The waterfowl areas with which I became most familiar include Scania at the southern tip of Sweden and the coastal waters associated with it, the wetlands lying to the northeast of Stockholm and centering about Norrtälje, some parts of the North Baltic archipelagoes, and the Boda–Söderhamn area of east-central Sweden. Briefer visits were made to that once-magnificent waterfowl marsh, Hornborgasjön, between Sweden's great lakes, Vänern and Vättern; to game-famous Jämtland; and to some of the northern wetlands of Västerbotten, Lapland, and Norrbotten.

Increases in latitude make remarkably little difference in the visible nature of the terrain in the Scandinavian Peninsula. Throughout forested Sweden northward from Scania on past the Arctic Circle, one can imagine himself in northern Minnesota virtually all of the way for 1,500 km. Hay lands and little fields of small grain in the valleys, potato patches bordering trout

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streams in the Arctic, oligotrophic lakes and rocky watercourses, lumbermen's cuttings and log rafts—these are what one sees.

One does see in Sweden more of dams and less of marshes than in northern Minnesota. The Swedes have gone a long way toward damming what can be dammed for hydroelectric power and draining what can be drained for agricultural purposes. There is, I should say, greater actual human domination of wildlife and wild lands throughout Sweden than in northern Minnesota and northward into Canada. Apart from Sarek National Park and certain other of the wilder mountainous areas, it is hard to find in Sweden many places, irrespective of how remote from the cities and larger villages, where one does not find man or evidence of man's recent presence. What I have seen of sparsely settled Sweden may more properly be called backwoods (or its mountainous or coastal equivalents) than genuine wilderness as we know wilderness in the wilder expanses of North America. Somebody seems to live or has recently lived in almost every place where a living can be made, from the tiny, crowded, and intensively managed farms in Scania to the fishing towns of the coasts and the reindeer ranges of Lapland.

FIG. 1. The Kävlinge River watershed of southern Sweden. The surface water covered 356 sq. km. or 29 percent of the watershed about 150 years ago (upper), compared with the present (lower) 41 sq. km. or 3.4 percent. Reproduced with permission from Wolf, 1956.

## IMPACTS OF ENGINEERING ON WATERFOWL HABITATS

In the doleful literature on misuse of drainage machinery, one can get the impression that Iowa's marshes may for practical purposes be considered drained, with such marshy remnants as are still present being largely in State ownership. I shall not deny that Iowa partly answers the question of how far the drainers may be disposed to go, but southern Sweden's Scania would appear to answer it more fully.

According to Wolf (1956), 29 percent of the Kävlinge River watershed was watercovered 150 years ago, whereas agricultural drainage has now reduced the surface waters to 3.4 percent of the watershed, and most of the remaining water is concentrated in a few lakes (Fig. 1). Wolf regarded the drainage of the Kävlinge watershed as representative of the whole of Scania.

Also according to a survey that Wolf made, the majority of the landholders affected by the drainage appraised it as a mistake, costing much more than any economic benefits that ever materialized from it. The survey did bring out many differences in viewpoints. Some people frankly regretted the loss of natural values, including the scenic as well as game and fish resources. Others justified the drainage, if in no other way, on the grounds that the marshes look better drained and the streams look better straightened.

The history of human tampering at Hornborgasjön has been treated at considerable length in the Swedish literature, earlier by Söderberg (1947) and more recently by Swanberg (1953; 1959). No other Swedish bird lake has been so thoroughly studied.

At one time, Söderberg had referred to it as the only large bird lake in western Sweden and as the most remarkable example of its kind in all of western Europe. Besides the writings of Söderberg and Swanberg, my principal source of information on Hornborgasjön was Sam Erlinge, who is not only a native of the area but also the author of a student dissertation on the origin and fortunes of the lake.

Hornborgasjön is 10 km. long and from 1 to 4 km. wide. It has been the object of several drainage attempts, beginning early in the 19th century, with the most nearly complete drainage dating to the mid-thirties of the present century. These drainings and redrainings added up to a costly failure in human land use. The drainage ruined some exceptionally valuable game and fisheries resources, it imposed enormous monetary expense upon the landholders, and the land thus "reclaimed" proved to be generally unusable as farmland. The venture has absurdities and lamentable aspects, all abundantly documented, that are reminiscent of our classic drainage fiascos in North America.

After the mistakes and misfortunes, it now appears that Hornborgasjön at last will be restored and protected as part of a well-integrated multiple-use project, with wildlife values, hydroelectric values, and agricultural values being considered in proper reference to each other. If any living person's name stands out in the arduous effort to save Hornborgasjön from remaining a weed patch, all but useless for most wildlife and landholders alike, it should be the name of Per Olof Swanberg, a dentist by profession but by avocation one of the dedicated conservationists of modern times.

In Denmark, I learned that some of the best remaining marshy areas had once been drained. In two outstanding cases (Vejlerne in northwest Jutland and Saltbak Vig in Zealand), the areas had reverted to a very good state for wetland wildlife after the failure, for technical reasons, of the agricultural drainage.

One area outside of Copenhagen was remarkable both for its abundance of birds and for the circumstances of its origin. It consisted of a large tract of former sea bottom, which had been diked and partly drained for military purposes. Danish ornithologists noted the responsiveness of water birds to the parts still retaining shallow water and asked if the drainage might stop at that point. The military personnel, already having sufficient dry land for their maneuvers, agreed to leave the rest undrained and have fully cooperated to make possible what is one of Denmark's richest bird areas of today.

Almost anything in the way of changes, favorable or unfavorable to the waterfowl, can result from hydroelectric development. Extensive impoundments in which the water does not fluctuate greatly may offset some of the deterimental effects of agricultural drainage. I visited by boat one such place (Dalälven, between Uppsala and Gävle, Sweden) having a wide, dam-flooded valley that was virtually a marshy lake over much of its area. It was well used by both migratory and nesting waterfowl. On the other hand, regulated streams subject to extremes of flooding or drawdowns may be among the biologically more undesirable places for waterfowl as well as for aquatic life. Fluctuations in water levels of 15 to 20 m. have been observed for regulated streams in northern Sweden, and large numbers of lakes are so regulated that they have sterile shore zones and little or no attraction for waterfowl (Bo Österlöf, *in litt.*).

## Extent and Quality of Waterfowl Habitats Remaining in Scandinavia

The quality of Scandinavian waterfowl habitats varies from poor to excellent, even in the same geographical areas at the same seasons of the year. Probably the best is afforded by the expanses of Swedish and Finnish archipelagoes in the Baltic Sea and the Gulf of Bothnia. These consist of thousands upon thousands of islands, large forested islands down to rocky islets, in belts as wide as 100 km. More land rises out of the very shallow sea at the rate of about a half meter per century at the latitude of Stockholm and at about twice that

FIG. 2. Nesting cover for ducks on a Baltic archipelago. Photo by Kai Curry-Lindahl.

rate at the northern end of the Gulf of Bothnia. The mainland coast may be a continuous succession of bays and peninsulas, wooded, brushy, grassy, or bare, with rocks and vegetation intermixed.

The archipelagoes comprise habitat that is primarily favorable for sea ducks, during both migration and the nesting season. Large flocks of long-tailed ducks (*Clangula hyemalis*) pass through, and the commonest nesting ducks that I saw were eiders (*Somateria mollissima*). Other common nesters are tufted ducks (*Aythya fuligula*), velvet scoters (*Melanitta fusca*), and red-breasted mergansers (*Mergus serrator*). Favored nesting islands that I especially remember were between ½ hectare and 2 hectares in size, rather sparsely grown to trees if they had any, but having irregular patches of ground vegetation suitable for concealment of nests (Fig. 2). Juniper masses offered good nesting places, and nests could at times occur in concentrations. A picture in one of Durango's (1940) papers shows an island at the north end of Gotland on which many currant (*Ribes alpinus*) bushes are visible; the caption explained that almost every one of these bushes had a velvet scoter or a red-breasted merganser nest beneath, with occasionally several nests beneath the same bush.

Archipelagoes are also habitat of dabbling ducks: In keeping with their ability to nest under a wide variety of conditions just about anywhere in Scandinavia, mallards (*Anas platyrhynchos*) may nest on the islands, and so may shovelers (*Anas clypeata*).

Human impacts on the archipelagoes may be extremely variable. The environmental features of the parts that I visited could not have been altered very much through human activities—that is to say, those parts away from cities and places that are becoming popular as sites for summer cottages. There is much that would seem to have sufficient nesting cover, proximity to feeding grounds, and privacy to suit the ducks adapted to breed in such places. Yet I know that few if any places are truly in-

FIG. 3. Wilderness in Sarek National Park, Swedish Lapland. Photo by Kai Curry-Lindahl.

accessible to people who want to go out there, that boaters invade the archipelagoes in tremendous numbers, increasing yearly, and that these visits may have a serious effect on nesting bird populations, even if the habitat is not affected.

I did not see enough of the Scandinavian tundra and mountainous regions at close range to justify firsthand appraisals as waterfowl habitat. However, some informative literature exists, and I have talked with biologists who have had long and detailed experience in the Lapland interior.

Tracts of land extending as far as 700 km. in one direction without roads worthy of showing in an automobile atlas provide space and water for the tundra and mountain species: the lesser white-fronted goose (*Anser erythropus*), the common scoter (*Melanitta nigra*), the scaup duck (*Aythya marila*), and the long-tailed duck. Mallard populations thin out decidedly as they approach this region, but the teal (*Anas crecca*), wigeon (*Anas penelope*), goldeneye (*Bucephala clangula*), velvet scoter, and goosander (*Mergus merganser*) are common nesters up there or near there as well as common nesters in many other parts of Sweden. The tufted duck and pintail (*Anas acuta*) have the Swedish tundra and mountains in their nesting range, also. Like their North American equivalents, these wilder areas do not consist exclusively of any one biotope; they may be dominated by tundra, willows and birch, coniferous forest, or mixtures of open bogs and forests (Figs. 3–6).

To some extent, the nesting species of waterfowl — especially the rarer — occur sporadically. Fewer than a hundred pairs of whooper swans (*Cygnus cygnus*) spread themselves out through parts of northern Sweden. Bean geese (*Anser arvensis*) nest in both coniferous and birch regions. The little merganser with the English name of smew (*Mergus albellus*) has a tiny nesting range in the northern third of the country.

Between the mountains and the archipelagoes in middle Sweden, some waterfowl production centers in the region about Jämtland. Although the larger watercourses may be much regulated by hydroelectric

FIG. 4. Wilderness scene from northernmost Sweden. Photo by Kai Curry-Lindahl.

dams and the lumberman's installations, many meandering creeks and natural lakes and marshes occur off to the sides. Nor, as previously mentioned, are the impoundments above the dams necessarily unattractive for waterfowl; they may or may not be. Jämtland's surface waters look about as suitable for the forest-zone types of waterfowl as do the waters of northeastern Minnesota. Here in Jämtland is strong nesting range of the goldeneye and goosander, with rather thinner populations of mallard and teal.

My statements concerning the Jämtland waterfowl range may also be applied to many provinces extending northward and southward. In Selma Lagerlöf's Värmland, an increasing beaver population has now, according to Bo Österlöf (*in litt.*), dammed practically all suitable brooks and lakes in the vicinity of Uddeholm and thus improved the area for mallards, teal, and goldeneyes.

Even in Jämtland, which has some of the best of the Swedish marshes, I should not rate the best that I saw as anywhere nearly as good as the best North American prairie marshes in overall waterfowl productivity.

Lakes dominate the wetland scenes away from the coasts from central Sweden south (Figs. 7 and 8). Entire marshes or prominent parts thereof may be grown up to dense reeds (*Phragmites*), but marshes of mixed cattail (*Typha*) and bulrush (*Scirpus*) emergents such as we know from the American north-central prairies are not very common, even in those parts of the south half of Sweden that still have undrained marshes. Fig. 9 represents an exceptional marsh for the parts of Sweden that I visited.

For hole-nesting species, the loss of dead trees removed by foresters has been partly offset by erection of nest boxes. There are localities in which the presence or absence of nesting goldeneyes may be related to the

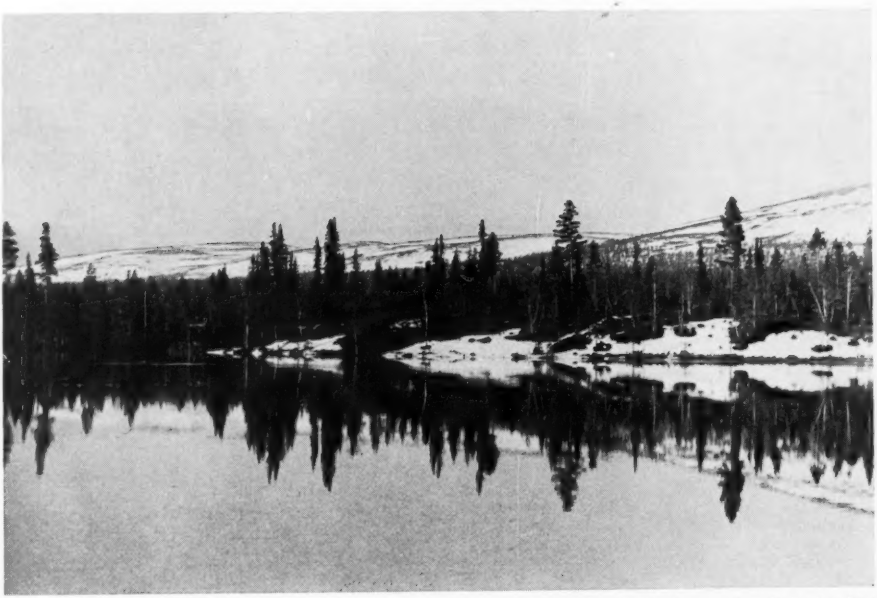

FIG. 5. West-central Sweden, with mountains of Norwegian boundary in background. Photo by Kai Curry-Lindahl.

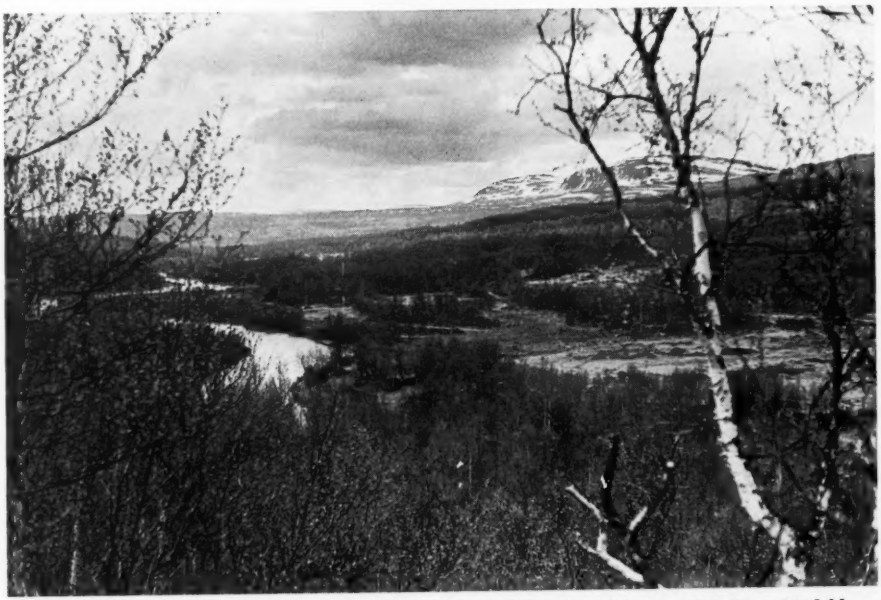

FIG. 6. Upper reaches of Ljusnan River in west-central Sweden. Photo by Kai Curry-Lindahl.

FIG. 7. South-central Sweden's "lake country." Photo by Kai Curry-Lindahl.

FIG. 8. Much of forested south-central Sweden looks like this. Photo by Kai Curry-Lindahl.

FIG. 9. An exceptional marsh, east-central Sweden. Photo by Kai Curry-Lindahl.

presence or absence of nest boxes.

In April and May, I worked east of Uppsala in the vicinity of Lake Erken, where reed-grown shores or bays had strategic importance for waterfowl. One concentration place had, in a tract a tenth of a hectare in size, 14 nesting pairs of great crested grebes (*Podiceps cristatus*), besides two coot (*Fulica atra*) nests, a mute swan (*Cygnus olor*) nest, two pairs plus two extra males of pochards (*Aythya ferina*), and many tufted ducks nearby. Within 600 m., two hollow oak trees had goosander nests. There were also many mallards.

Over much of the mallard's breeding range in Sweden, pairs appeared here and there, perhaps a pair or two having a whole lake or wide bay or a good patch of shallow-water vegetation to themselves. Considering the tremendous numbers of small- to medium-sized lakes and reed-grown bays of larger lakes stretching northward from Scania, Sweden's total nesting population of mallards could be larger than one might judge from the apparently sparse distribution of the species. I could not help feeling that there should have been more mallards in this region, whether the lack of mallards might be due primarily to habitat deficiencies or to insufficient numbers of birds to populate the habitats that they did have.

In Scandinavia as well as in other parts of the mallard's range, there could be a confusing unevenness in local nesting populations. The most heavily populated nesting area of mallards that I saw was an island among other islands, and I could see nothing distinctive to explain the partiality of the mallards toward that island over some of the others. One of the principal research projects of Marcström and Höglund in central Sweden has as its purpose the investigation of habitat features that affect the mallard's selection of specific places for nesting and rearing.

Local establishment of traditions (in the sense of individual waterfowl returning to nest at or near the same sites year after year or young birds showing sufficient attachment to the places where they were

reared to return there to nest) should be considered especially in relation to the building up of populations of the so-called "park ducks." A distinction should here be made between the truly migratory birds, which live in association with man only at some times (as during the nesting and rearing months), and the birds that are habitually or characteristically year-round residents of cities and estate grounds.

The Scandinavian countries have many mallard populations of the latter type, comprising many thousands of birds that remain as residents, often with the aid of artificial feeding and pampering enough to take them quite well along the way to domestication. Although such semidomestic populations are probably on the increase and with prospects for substantially more increase to come, they may not be regarded as wholly a good thing from the standpoint of the welfare of Scandinavian waterfowl. Even so, they may not be wholly a bad thing, and the formalized parks and gardens do provide some livable substitute for biotopes that are lacking naturally or have been lost through human occupancy of the land.

Artificial propagation, especially of mallards, has long been a management measure in many of the more thickly settled parts of Scandinavia. In a limited and rather strained sense, I suppose that the nesting cages of the game breeders' birds or the incubators may be considered a substitute for the vanished natural nesting sites for wild birds, for the marshes that Denmark and southern Sweden had before drainage; but, as a contribution to the broader aspects of Scandinavian waterfowl or wildlife management, I cannot see that this sort of propagation adds anything desirable.

Wintering areas of waterfowl in Scandinavia are chiefly along the coasts of Denmark and southern Sweden, though I saw many wintering mallards in Oslo Fjord and know that some of the cold-water ducks such as longtails and scoters include in their wintering ranges the coasts and sea between northern Norway and Iceland. Indeed, the extremely long Norwegian coast represents an important wintering range for grebes, gulls, auks, cormorants, both dabbling and diving ducks, and small groups of whooper swans. Most of the Swedish side of the Gulf of Bothnia can also be within the wintering range of some species of ducks, but occasionally the gulf freezes over, as may the Baltic Sea, and most disastrously for birds such as tufted ducks that fail to adjust (von Haartman, 1957). The same sort of thing can happen to waterfowl wintering away from the open sea along the Danish coast, when the more sheltered bodies of water freeze over.

If the weather does not become overly severe, many waterfowl may winter in southern Sweden's estuaries, Scania's lakes, and Denmark's bays and inland waters. When the Scanian lakes froze over during my stay there, wintering mallards and bean geese massed along flowing streams or out on the lake ice next to the few places having open water. In northern and northwestern Jutland, I saw immense aggregates of ducks, geese, and swans sitting on marsh ice in January; the remaining patches of open water were shrinking daily, and it could be seen that these birds might soon have to move on or starve if the cold weather continued.

For the northern wintering grounds, suitability for the waterfowl species that stay looks more like a matter of food than any other factor, with the possible exception of direct or indirect protection from man. The birds that can live upon fishes or invertebrates of unfrozen waters can usually manage well enough. So can the plant-eating forms that have the necessary access to edible marshy growths (especially nutritious rootstocks) or to the products of cultivation—waste grain, green pasturage, or food put out for them by sympathetic people. Besides the mallards, the geese and swans may be good winterers in man-dominated Scania and Denmark, and so may be diving ducks about harbors that are kept open. Stockholm's open water may winter, besides a few hundred mute swans and many thousands of mallards, many hundreds each of coots, goosanders,

and tufted ducks (Engström och Ehrström, 1957).

### EMERGENCIES AND SCANDINAVIAN WATERFOWL

Aside from the often inconsequential but sometimes cataclysmic losses of waterfowl resulting from hard freezing of water on their wintering grounds, the outstanding source of emergency loss to which these birds are subject in and about Scandinavia is oil on the surface of the sea.

The seabird victims of what Scandinavians call the oil death may be reckoned in vast numbers. Published references exist to such occurrences as 30,000 oil-killed long-tailed ducks along the coast of one Swedish province. The longtails, among other ducks, are attracted to the quiet-looking oil slicks on rough water; and, as a principal wintering species along the Swedish coasts, they are at times particularly vulnerable to the oil death.

It does not necessarily happen that every bird that gets oil on it is doomed. On the banks of Oslo Fjord in late winter, I got close-range views of some mallards with rather conspicuous oil smears on their breast feathers, and at least some of these seemed to be quite functional birds. Maybe that was because they could stay on land and keep warm by roosting on straw and ground vegetation. The destruction of the insulating and waterproofing properties of the feathers by oil explains the inability of water birds to stay out on the cold water. The birds chill after the water comes in contact with the skin of their bodies. Oil-drenched feathers also prevent normal flight, diving, and food-seeking activities of water-bird victims.

The worst smeared stretches of coast that I saw were along northwest Jutland and in the Helsinki archipelago. Compared to what I have read about, these places were probably not more than moderately bad. One account cited an instance of 30 k. (66 lb.) of oil per day having been washed up along a 150-m. stretch of beach in southwest England over a 2-month period. At any rate, I saw enough oily coast and mummified bird carcasses with oil on their breasts to get some slight first-hand idea of what a curse the oil can be. Even apart from its deadliness to bird life, the foul mess that it can make of seacoasts is nothing joyous to contemplate.

Waterfowl losses from freezing over of wintering grounds are well documented in the literature from northern Europe. During the 1939–42 period, practically the whole Baltic Sea froze for weeks. A hard winter reduced by half the population of tufted ducks in a part of a Finnish archipelago studied between 1935 and 1955 by von Haartman (1957). Goosanders, goldeneyes, and longtails are among the victims frequently reported—about 100 goldeneyes were frozen in what had been a last patch of open water about 20 sq. m. in area (Nordberg, 1950). Possibly the most dramatic mortality of all in recent years concerned not ducks but the razor-billed auk (*Alca torda*), of which almost the whole Baltic stock was wiped out in the early and mid-forties. Still, it is often surprising what capacities waterfowl have to endure winter emergencies.

The Scandinavians as yet have no problem of either lead poisoning or botulism poisoning in their waterfowl. They are greatly worried about the possible effects of herbicides and insecticides on wildlife generally and have investigations in progress. I should say that at least the Swedes seem disposed to tighten their legal restrictions on the use of toxic sprays, whether or not that has any special bearing upon waterfowl biology.

Northern Europe does have diseases and parasites that could affect waterfowl, rather after the fashion of emergencies, so some mention of them will be made here.

Although I know of no epizootics of *Salmonella* in or very near Scandinavian waters, German pathologists have observed serious epizootics in populations of water birds of places to the south, and infections do occur in Swedish and Danish gulls (Borg, 1960). The acanthocephalan parasite known as the thorn-headed worm (*Polymorphus boschadis*) destroyed a third

of the eider population of the southern coast of Finland in the early thirties (Lampio, 1946). Parasitism by this organism is also widespread and locally serious on the Swedish side of the Baltic. Its effects on the health of the hosts are considered by some observers to have accentuated starvation crises during ice winters, even to the extent of preventing the final recovery of many birds after the ice had gone out. One may easily see how this parasite could be deadly; the parasites attached to the linings of alimentary tracts of birds may look like coats of wet feathers growing internally. Karl Borg, a Swedish government veterinarian whose work deals much with game diseases, considered starvation of primary and parasitism of secondary importance in the mortality of the adult birds, while the parasitism itself was probably responsible for heavy juvenile losses during the summer months (*in litt.*).

### PREDATION AND SCANDINAVIAN WATERFOWL

Many Scandinavians ascribe much significance to subhuman predation as a depressive factor in waterfowl populations, and this was one of the subjects about which I made special efforts to learn what I could throughout my stay in Scandinavia.

The Swedes are particularly concerned with depredations of the introduced North American mink (*Mustela vison*) upon their waterfowl, and they (as well as the Norwegians) have research on food habits and behavior of wild minks under way. So far, it has been difficult to appraise the available evidence, such as instances of conspicuous local predation upon ducks and ducklings of nesting concentrations and a most confusing array of sometimes careful, sometimes offhand, usually scattered, observations by the outdoor public.

When a mink gets into an enclosure and kills the helpless ducklings, no one need be surprised, whether in Sweden or North America; and, when ducks, including incubating females, occasionally fall victim in small numbers here and there, such would not be exceptional on either side of the Atlantic; but, when the reported predatory exploits of the mink in Sweden seem much in contrast with what is commonly to be expected of the species in its native North America, one may wonder if lack of racial experience of northern European waterfowl with the North American mink might not be a partial explanation for some of the differences.

Certainly, I have the secondhand impression that the exotic mink exerts pressure upon the previously mink-free Icelandic avifauna of an intensity that far surpasses anything that I ever witnessed in the strongest "mink country" of north-central United States and adjacent Canada. Even though the Scandinavian Peninsula has no native species of minks, other regions of continental Europe do have, and thus many of the Scandinavian waterfowl species must have had racial experience with at least some minks during migration if not at other times. Would mink pressure upon waterfowl of the Scandinavian Peninsula be intermediate between that of the reported Icelandic intensity and the relatively benign-looking predation upon waterfowl that the mink–waterfowl studies in the north-central states have tended to show?

(There is surely plenty yet to learn about mink–waterfowl relationships in North America, but I should say that a great deal of the evidence suggests age-tested adjustments between minks and their typical avian prey in regions where both are native. The two most notable examples of mink predation upon waterfowl—one case involving mixed species of ducks in Montana and the other young coots in northern Iowa—that I ever saw were striking: Hundreds of mink droppings were made up of remains of these birds, and dead bodies were strewn about trails, about entrances of holes, and about openings in vegetation used as feeding places by the minks. The marshes where this predation occurred were also the sites of such concentrations of vulnerable waterfowl that it would have been surprising if the minks had not exploited them heavily while they had the chance. Moreover, there is no doubt that a large proportion of the minks' exploita-

tion of waterfowl during migration can be centered upon dead birds or upon the crippled, lead-poisoned, or otherwise handicapped. The biggest questions that I see in mink–waterfowl relationships in North America have to do with predation borne by normal birds living at what may be called the more normal densities and with the overall population significance of the predation suffered. Until we fill in the gaps in our knowledge of mink predation on its native waterfowl prey in its native geographical range, the technical obstacles to assessing mink predation on racially new prey populations in a racially new land must continue to tbe enormous.)

Further complicating the problem of studying mink predation upon Swedish waterfowl was the apparent scarcity of minks in nearly all areas where intensive field work was done, including areas selected for study because of the reputed abundance of minks. In Jämtland (which is the center of some of the most vehement complaints about minks), mink "sign" could be found only in a small percentage of the places looked over and in not anywhere nearly the quantity commonly to be expected about lakes, marshes, and streams of similar types in north-central United States. Throughout my travels in Sweden, I saw few areas that I would consider as good as second-class biotope for minks compared with the best in North America. The wetland area having the strongest mink population that I saw in all of Scandinavia was the celebrated partly drained marsh, Hornborgasjön. This had a moderate mink population according to the standards observed for glacial marshes of Iowa and the Dakotas. The highest Swedish catch figures that I found were about 200 for the winter of 1958–59 from an area of 20,000 hectares of State Forest similar to central Minnesota's wooded lakeland. It is noteworthy that about 200 also represented a peak-year catch on about 3,000 hectares of the Lake Oakwood and Lake Tetonkaha area of east-central South Dakota for the winter of 1921–22, when I was a trapper living on the area. Bo Österlöf wrote of 63 minks taken in 1959 from 35,000 hectares in the Storfors area, which he regarded as a good catch (*in litt.*).

I did find evidence that in Sweden the mink is less aquatic than is commonly the case in north-central United States. It was true that the mink frequented some of the water areas in Sweden that one might have judged most attractive to the species, but mink "sign" also occurred up in the woods or about the borders of fields. Superficial examination of mink scats indicated that small rodents made up a large proportion of the prey even of the minks working stream borders during the warm-weather months.

I was closely associated with a study carried on by Erlinge on the otter (*Lutra lutra*) in southern Swedish waters and have read an unpublished report on the results of his first year of work. This report summarizes the contents of 8,299 freshly gathered otter scats plotted according to weekly intervals for his two principal study areas, the lake, Sövdesjön, and its outlet stream, Klingvallsån (Fig. 10). Of 4,790 otter scats from the lake, 111 contained recognized mallard remains, as did 78 of 3,509 scats from the stream. (Other waterfowl representations included 58 and 12 of coot for the lake and stream collections, respectively; 35 and 6 of goosander; and 4 of crested grebe from the lake. Undetermined bird remains, which could have included some waterfowl, were listed for 147 of the lake collections and for 85 of the stream collections.) For the entire collection of 4,790 lake scats, 554 or 11.6 percent contained bird remains, compared with 198 or 5.6 percent for the 3,509 stream scats. Of all of the birds the remains of which were identified, the mallard showed the greatest number of representations—189 or 2.3 percent, as against 138 or 1.7 percent for the starling (*Sturnus vulgaris*), the bird having the second highest number of representations. (The starlings may either have been good prospects as otter food because of their habits of night-roosting in the reed growths of the lakeshore shallows, or their bodies may have been available to scav-

FIG. 10. A stream in southern Sweden that especially attracts otters and wintering waterfowl if the lakes freeze over. Photo by Gunnar Markgren.

enging otters in consequence of insecticide poisoning [Enemar, 1958].)

In the discussion section of his report, Erlinge brought out that the highest incidence of mallard remains (34 representations in about 280 lake scats) occurred between May 23 and June 23, when newly hatched young were available. During the summer and early autumn, a young duck or a moulting adult would be taken now and then. Occasionally, the otters would feed upon ducks during the fall migration, when variable numbers of waterfowl visited the lake.

With the freezing of the lake in January, the ducks congregated about the stream, which remained partly open; and, during the first cold snap (January 14 to 23), 47 of about 250 scats contained mallard remains, representing, so far as known, 4 or 5 individual mallards of the 300 to 400 wintering in that restricted area. When the lake became frozen over again between the last of January and February 23, there were about as many ducks frequenting the stream as under similar conditions before, yet only 5 of about 600 otter scats were found with mallard remains (representing 1 or possibly 2 individuals). The latter low representation occurred despite the fact that several otters were using the stream and that one of their number was a large otter that had been showing a propensity for feeding upon duck flesh. During the whole spring until the end of May, mallard remains were found only sparingly in the otter scats (5 representations in about 800 lake scats and 4 in more than 1,000 stream scats from February 23 to May 14).

Further adding to the difficulties of satisfactorily appraising otter predation was the fact that the otters could, at times, live to a significant extent on carrion. I saw fair numbers of fall and winter otter scats that contained mallard or goosander remains, but there seldom was visible evidence associated with them to indicate whether these representations were of car-

rion or of killed prey. The same could be said regarding the duck-containing eagle pellets gathered from the vicinities of Scania's lakes. Crippled or ailing ducks and geese could be seen from time to time, and it was apparent that both otters and eagles (*Haliaeetus albicilla*) could find some waterfowl flesh without working very hard for it or killing sound birds.

On the archipelagoes, sea eagles have a reputation for being duck killers. Grenquist (1948) wrote of 1,702 pairs of eiders nesting on a total surface area of 110 hectares of land in a Finnish archipelago bird refuge, where 60 eider females were taken from their nests by sea eagles during the summer of 1930. This predation not only coincided with one of the two peak populations of eiders for the 1921–40 period but it also immediately preceded a year of great mortality from thorn-headed worms. Grenquist considered the possibility of whether the eider population may not already have been debilitated from the parasitism at the time of the heavy predation.

The above eider concentration does not represent a nesting density anywhere nearly as high as eiders can show. Salomonsen (1945) gave a maximum figure of around a thousand pairs of eiders on the 11-hectare Danish island of Graesholmen (near Bornholm) in 1943, besides some thousands of other nesting sea birds. Such differences can in part be attributed to differences in availability of the main eider food, the mussel (*Mytilus edulis*), which is favored by high salinity.

The intense hatred and illegal persecution of sea eagles by fishermen of the Swedish and Åland archipelagoes (irrespective of the precarious status of sea eagles, the populations amounting to 40 to 50 pairs in Sweden and about 25 pairs in Finland) are said to reflect jealousy toward the eagles for their predation upon eiders as well as for any damage the eagles are thought to do the fishes. Whatever may or may not be the factual basis for such extreme views, eagle predation upon eiders has often been witnessed in places where both eagles and eiders occur.

Johan Willgohs, of the Zoological Museum at Bergen, summarized for me the sea eagle situation in Norway (*in litt.*): About 300 pairs breed along the coast from about 61 degrees up to East Finnmark. Of 821 items of prey for which he has record, about a third consist of eiders and about 44 percent of the total consist of sea birds collectively. He does not regard the eagles as actually being any menace to the eider population, though they are persecuted in part for depredations upon rookeries of sea birds. Other reasons given for persecution of the eagles in Norway are the bounty payments and the "more or less justifiable suspicions" of eagle predation upon sheep and goats.

Eiders may be highly vulnerable to predatory mammals such as foxes, and this vulnerability makes their island-nesting habits understandable. The island of Rømø off the southwest coast of Denmark at one time had a thriving eider colony. After the building of a highway from the mainland, the foxes came out, and that ended the attractiveness of the island for nesting eiders. The disappearance of nesting eiders from Rømø did not exclusively represent mortality of the nesting eiders through fox predation, for the birds adjusted by colonizing a nearby foxless island.

Apparently, the eiders of the Baltic and Bothnia archipelagoes do very limited renesting in the event that their nests are abandoned or plundered, but nesting success can be high—up to 70 percent. Eider ducklings may draw predation, as from gulls. Göran Bergman informed me that losses of young eiders may vary from 25 to 95 percent; in June, 1960, the loss in the Helsinki–Porkkala area was 95 percent of the young in their first week of life, for which he considered the very cold sea water responsible. We need far more data than as yet exist to regard the significance of variations in reproductive success and mortality rates in broad perspective.

Recent work by Koskimies (1955; 1957) on the yelvet scoter in an archipelago off the southern coast of Finland raises important questions. Although about three-quar-

ters of the scoter eggs produced young, the survival of the young was so low—virtually no survival in the worst years and only a small percentage in the best — that the population could not be considered self-sustaining through its own productivity. Koskimies did not regard the longevity and the fidelity of the old birds to particular places as a full explanation for the way that local populations could hold up (or continue to gain), the severity of juvenile mortality notwithstanding. He believed that a population influx must also occur.

Koskimies made the distinction that the velvet scoter was originally a species of small inland waters of the northern coniferous zone and that its abundant nesting in the Baltic archipelagoes is a relatively late phenomenon. The ecological differences characterizing this scoter's original and more recently acquired breeding habitats are obviously pronounced; and it is understandable how fixed, conservative adaptations of the species to fit the requirements of its original habitat could not be wholly suitable for transferring to a different habitat. The following features were listed as basically responsible for the high juvenile mortality under the maritime conditions of the archipelagoes: extremely loose bonds between parents and young, a tendency to overcrowd brood-rearing areas, and sensitivity of the young to bad weather.

In the inland waters having restricted dimensions, close attachment of broods to mothers does not have the survival significance that it has in the open archipelagoes where nothing sets a limit to the straying of the young. Congregation of young broods in given areas of the archipelagoes adds further complications. Fighting or other contacts frequently occur between members of strange broods. Individual mothers do not hold their own broods, while other mothers may collect from various sources more young than they can care for, as aggregates of 30 to 40 young. In addition to the vulnerability to predation upon aggregates of broods of mixed origin having loose family bonds—especially to predation by large gulls—there is the question of whether aggregates of young in archipelagoes may not deplete locally available food resources. Superimposed upon all of the other disadvantages of the Baltic archipelagoes for young scoters is that of lower and more violently fluctuating temperatures of the surface waters compared with the temperatures of the inland lakes. It is notable that the very late brood period of the velvet scoter (average hatching date being mid-July) coincides with the average maximum temperature of the northern inland waters. Koskimies has made a fine study, with broad ecological and management implications. He speculated as to what would happen if some of the scoter populations now regularly breeding in the archipelagoes despite little or no success became dependent upon their own productivity alone. How long, he asked, could a species like the velvet scoter afford, biologically, to have large marginal populations squandering their reproductive efforts in biotopes in which they lack the adaptive resilience really to belong?

Or might the phenomenon be principally one of population overflow or of the types of wastage that are not selected against as long as overflow birds continue to take the place of sustaining reproduction? This leads to the old questions of balancing and counterbalancing that conceivably could offset many of the postulated advantages of high local productivity and the postulated disadvantages of low local productivity. It would be fair to ask just how much these possibilities could apply to other waterfowl, when we try to appraise vital statistics on the basis of "obvious" limiting factors, tabulated data, and spectacular local or even regional changes in natality, mortality, movements, and status of biotopes. Of course, we may come around to the specific and general aspects of just how the population significance of predation fits into the balancing and counterbalancing, how much real difference it may make whether predation be light or heavy (Errington, 1956).

It may also be asked how much the findings of Koskimies on the velvet scoter

might have counterparts in the current extension of the breeding range of the mute swan into the Swedish and Finnish archipelagoes. The impression that I have from talking with Swedish ornithologists is that the archipelagoes furnish marginal habitat for the swans and that swan production there may not be what it is on the reed-bordered inland lakes comprising the stronger biotopes. Bergman noted that the swans are now colonizing the archipelago in southwest Finland before breeding in some of the better inland biotopes. Swans may be near saturation densities in many areas, such as inland from the Norrtälje archipelago north of Stockholm. To some extent the archipelago swans may be classified as overflow birds, as population surpluses that are tending to become too marginally situated to retain their productivity.

Some of the most puzzling questions on predator–prey relationships have to do with goshawk (*Accipiter gentilis*) predation upon some medium-sized birds, including ducks. It is now rather plain from studies of the lesser accipitrine hawks in both Europe and North America that these hawks in reality do not have the ability to take prey under all circumstances, that the hawks may make many unsuccessful attempts to capture prey for every attempt that succeeds, and that such factors as nature of the terrain and behavior of the prospective prey may decisively influence the chances of the prey for escaping. Thresholds of security, familiarity with surroundings, and what may be called social ease or the psychology of confidence all may give the prey species sufficient advantage to complicate the hunting problems of Cooper's hawks (*Accipiter cooperii*), sharp-shinned hawks (*A. velox*), and the European sparrow hawks (*A. nisus*). Concerning these latter points, Rudebeck's (1950–51) two-part paper on choice of prey and modes of hunting of predatory birds contributed some of the best data and discussion that I ever found.

I saw enough of predation of Swedish goshawks to compare with what I had seen in North America, and what stands out from my experience with both is an awareness that both can hit some species hard—and yet under conditions that afford little basis for judging exactly what is happening. I am not satisfied when viewing the evidences of murdered grouse and wood pigeons (*Columba palumbus*), for example, merely to conclude that the goshawks could select these species and prey upon them at will, for the primary reason that the predators and prey were simultaneously at the same place. That looks too easy for an explanation. Goshawks are formidable predators but they should not be formidable beyond comparison with their smaller relatives.

Gunnar Svärdson told me of the near-destruction through goshawk predation of a population of mallards nesting on an island in the city of Stockholm, but this predation was incomparably the most drastic of which I have read or heard in Scandinavia or anywhere else. The case also had its unanswered questions as to both the status of the ducks (whether the ducks were excessively crowded, inexperienced with respect to predators, softened by semidomestication, or otherwise unusually vulnerable) and the full capabilities for deadly attacks on the part of the goshawk as a species. Indeed, the case seems unique in the experience of Scandinavian waterfowl students. Göran Bergman, who has worked intensively with Finnish waterfowl for many years, knew of no evidence of anything like it in Finland, nor of any material predation by goshawks upon ducks. Sigfrid Durango (*in litt.*) often saw goshawks trying to catch ducks of the ditches and small streams in the vicinities of four goshawk nests that he had under observation; the pursued ducks would press in close to steep banks and regularly escape.

Still unanswered are questions as to population effects of some interrelationships of waterfowl that can be either interspecific or intraspecific in nature, especially concerning impacts of predation that may be conditioned by the social relations of the

prey itself. Increases of parasitic egg-laying or nest parasitism that can accompany crowding (as on islands) may result in much reproductive wastage, some of which is manifested incidentally by increased availability of waterfowl eggs or young to predators. Laying of eggs in the so-called dump nests, abandonment of clutches, knocking eggs out of nests by competitive females, irregularities in hatching, mixing of broods, poor care of broods, and general deterioration of the breeding effort as a result of the confusions, distractions, harassments, and weakening reproductive impulses of a highly competitive situation, all may be expected to increase vulnerability to predation.

Durango (1940) found that, on islands having dense nesting populations, some species of ducks may engage in almost general laying in each other's nests. Eggs of as many as four species of ducks have been reported for a single nest, with shelduck (*Tadorna tadorna*), red-breasted merganser, velvet scoter, and eider being among the ducks most inclined toward parasitic laying—though parasitism by the latter three of these species may be rather uncommon under conditions of lesser crowding. In Scandinavia as in North America, diving ducks of the genus *Aythya* include some of the most habitual parasitizers and their victims (for a thorough treatment of parasitic egg-laying in an *Aythya*, see Weller, 1959). Lars von Haartman (*in litt.*) considers the tufted duck the best known for its parasitism of duck nests in Scandinavia and the pochard as one little inclined toward parasitic behavior.

Often the eggs of the different species do not hatch at the same time in these mixed clutches, which results in many unhatched eggs left exposed in nests after the incubating female leaves with the hatched young. Then the fate of the young of the different species may vary greatly after hatching, as in cases in which much parasitism spreads miscellaneous young throughout a concentration area, as well as where splitting and recombining of broods occurs even when the young remain attached to their proper species of females if not to their own mothers.

Under such conditions, two contrasting phenomena tend to increase vulnerability to predation: the straying or getting lost on the part of many of the young and the ganging-up of large numbers of young followers of certain adults. Cases may be reported of 30 to 50 or even more young being under the hardly efficient protection of a single eider, scoter, or merganser female. A brood like that could be nothing else than a compelling attraction for opportunistic predators that happened along.

In attempting to generalize concerning what we know or do not know about predation upon waterfowl, one might feel safe in concluding that the tendencies of many species toward crowding in local areas may underlie much of the severity (or the conspicuousness) of the predation suffered and the difficulties in satisfactorily appraising the population effects of such predation.

## HUMAN EXPLOITATION OF SCANDINAVIAN WATERFOWL

Norway exerts the lighest hunting pressure upon waterfowl of any of the Scandinavian countries, though the dense nesting concentrations of eiders in Norway's Atlantic and Arctic archipelagoes are exploited for down and to some extent for eggs. The principal species shot along the southern coasts are the mallard and two species of scoters shot in late fall during traditional hunting for razorbills and guillemots (*Uria aalga*) (Yngvar Hagen, *in litt.*). This light hunting pressure seems to be less due to a scarcity of ducks—which can be seen wintering in fair to strong abundance in fjords and out from and along the Norwegian coast — than to the fact that Norwegians as a people do not seem to care so very much about duck hunting.

The situation is different in Denmark (of which the Swedes and Finns are certain), in Sweden (of which the Danes and Finns are certain), and in Finland (the Finns do not deny that they kill ducks, but the Danes

and Swedes do not seem so concerned about what the Finns kill as Danes do about what Swedes kill and Swedes do about what Danes kill). Southwestward from the west coast of Denmark, down in German, Dutch, and British waters, there is also killing of waterfowl by hunters, but what I heard about in Scandinavia was the amount of killing done by the Danes and Swedes. The latter topic can be a sore point among the Danish and Swedish hunters, and it is by no means evident which faction has the most truth and justice on its side.

Koskimies (1956) reported that, according to his material, over 60 percent of the mallard population originating in Finland is shot outside of that country, the largest proportion in Denmark and the next larger in Sweden and France. Denmark is also the center of recovery for notable numbers of ducks banded in other countries of northern Europe, especially in Britain, Holland, and Sweden. The Danes counter the accusations that they kill more than their share with questions as to whether they merely are not more conscientious about reporting bands.

(It is quite true that birdbanders are worried about the possibilities that embarrassing publicity may jeopardize the effectiveness of the waterfowl banding program through making hunters or hunting organizations reluctant to turn in bands; and I have heard Europeans ask, in effect, why should hunters cooperate only to have the information they contribute used against them? There are problems in human relationships as well as in technical aspects here.)

As Aldo Leopold wrote years ago, the European legalities and customs of considering ownership of the game as part of the rights of land ownership worked for the disadvantage of migratory species, however carefully the year-round resident game might be harvested. But the idea of taking the migrants while the taking is good is nothing peculiar to Scandinavians or other Europeans. Nor can I appraise the actual effects of the more unrestricted shooting (or harvesting by other methods), the legal selling of game, the special dispensations, etc., that may be permitted Scandinavian hunters or landholders.

My own observations on European waterfowl hunting relate entirely to what I saw in Sweden, so I shall have to restrict to that country my comments on what seem the practices that tend most to add up to excessive hunting pressure.

Lack of bag limits may not, in practice, operate as perniciously as its "paper potentialities" might allow. Although I saw old references in Swedish game journals to immense bags of waterfowl in a single day, the modern waterfowl bags that I happened to see were within (or certainly not much in excess of) present-day American bag limits. Often the bags were of only a bird or two, if anything. I never did get at the time of my visit any impressions that game-hog bags were favorably regarded by Swedish sportsmen.

When I sent a preliminary draft of this article to Scandinavian colleagues, I got back some current examples of excessive shooting that are worth recording: A Finnish industrialist having particularly good opportunities in the Aland archipelago would shoot hundreds of male eiders in 2 or 3 days. On June 1, 1960, a Finnish fisherman shot 99 male eiders. In Scania, some hunters shooting over heavily baited small ponds (especially those of marl-diggings) may slaughter ducks in great numbers during evening flights, in "scores per gun . . . a kind of abuse which present legislation cannot prevent." But it is true that over the greater part of Sweden waterfowl do not occur in shooting-season concentrations that would often permit slaughtering.

European waterfowl do have the advantage of being exploited by few people compared to our millions of licensed waterfowl hunters in North America and the mobs of hunters that may gather on favorite or accessible American shooting grounds on the opening day of the hunting season or during large-scale migrations or a much-anticipated and much-advertised "northern flight." When I told Swedish hunters about the mass barrages at all ranges that were

such discouragingly commonplace sights on some Iowa or Dakota marshes, they invariably responded by saying that they were glad to have their hunting as it was.

The practice of shooting during the long northern twilight, which I repeatedly observed in Scania, surely increases the kill of waterfowl that have become so wary that hunters have great difficulty getting near enough to shoot during full daylight. I have had bean geese in flocks of hundreds pouring past over my head in the dusk, within shotgun range at times when shooting could be heard elsewhere about the lake.

Shortening of the hunting seasons and delaying the opening dates for Scandinavian waterfowl very possibly might result in a substantial lessening of the hunting toll. As the seasons stand, I think that they start too early in Sweden. Perhaps I am prejudiced by an American viewpoint, but I have been unable to see justification in beginning the shooting as early as August, and least of all in southern as well as northern Sweden. And I think that the shooting of at least diving ducks continues too late in Denmark, continuing through February, very near if not up to the time when the spring migration northward begins. (For dabbling ducks, the Danish season extends through December.) Spring shooting in Sweden, which until recently has been permitted under special restrictions, is now forbidden.

The recent abolition of spring shooting in Sweden is credited with a fivefold increase of the eider population in adjacent Finland, though I am not sure how well a cause-and-effect relationship could be demonstrated. In the Stockholm archipelago, according to Westman (1956), the most pronounced increases occurred in parts on which the spring shooting had been a traditional practice, whereas somewhat less increase was noted in parts on which spring shooting had not been carried on.

As concerns shortening the shooting season on the autumn end, one may at this time only conjecture as to the degree of protection that might thus be given the birds, and then largely on the basis of North American experience. It may be a permissible generalization that the ability of at least some young ducks to adjust to gunfire is conditioned by whether or not their experience with shooting starts before or after they leave the localities where they were reared. The writings of Hochbaum (1947; 1956) are particularly suggestive as to this distinction.

The phenomenon of "burning out" of locally produced birds and consequent progressive reduction of local breeding stock has as one of its manifestations a panicky flying back and forth from one familiar marsh to another after the opening-day shooting starts. Such innocents can be slaughtered in short order if enough hunters are there to do it. Yet, once the birds leave their rearing grounds and become part of the normal migratory movement, they seem to be much less susceptible to the killing that tends to depopulate local breeding areas, though they may still be subject to hunting. A delayed season has the further advantage of allowing locally reared birds more of a start toward the maturity that only sufficient time can bring. Koskimies found that 85 percent of the Finnish-reared mallards were still in their home areas as late as September.

There may be determined opposition to moves to delay the opening of the waterfowl hunting season. The opening date for southern Sweden has been the first of August. The expressed justification of this is that such early shooting permits the people on whose property the birds were reared to harvest their share rather than letting them go on to be shot by someone else. But, theoretically, even the southern Swedes should benefit from lightened local pressure upon their home-reared ducks even if someone else benefited more, insofar as more ducks successfully leaving their breeding grounds in southern Sweden could result gradually in more coming back there to breed.

Of course, in Scandinavia and northern Europe, as in North America, the problems of human relations and arriving at local,

regional, and international agreements that would be equitable and biologically sound must always be among the most difficult. The laws should be right, and so should be their enforcement and the attitude that the public shows toward the laws — and so should be the public's attitude toward the elementary aspects of conservation biology. When the law is not enough to meet a situation, informed public opinion may make up for the difference; and public opinion among Scandinavian hunters can be a strong influence for good when well directed. I remember the scorn with which the legally permitted potshooting of a mother goldeneye and her flightless brood was depicted and publicized. The word for poaching is, literally, thief-shooting, and my impression remains that the standards of conduct in the educated hunting public are high.

What can take place out in the far reaches of the archipelagoes or "back of beyond" in forests or mountains may not necessarily reflect high standards, however, and adequate law enforcement should have a proper part in Scandinavian waterfowl management. When one reads about half of the female eiders of tracts of archipelago having been killed for the black market in a single season while they nested, or about substantial areas becoming virtually depopulated of nesting waterfowl through years of conscienceless raiding, the need for effective legal control becomes apparent enough. There must be agencies in authority, willing to "crack down" on the more destructive violations.

My impression is that Scandinavian law enforcement agencies are understaffed with respect to protecting waterfowl, but that the disadvantages resulting therefrom are offset in part through good cooperation with hunters' organizations, nature-protection groups, and the better class lay public.

One measure that could be advocated for the betterment of overexploited stocks of Scandinavian waterfowl would be the establishment of more refuge areas both on wintering grounds and along major migratory routes. The Danes already have a good start on a refuge system, which could well be expanded. There are many areas along the Swedish and Finnish coasts that should offer suitable biotopes and strategic situations for migratory bird refuges or perhaps for nature preserves that would be valuable for migratory bird refuges as well as for other purposes. Some effective refuges do exist in these areas, but I am sure that more are needed.

In Sweden, there is a growing movement for the establishment of representative parts of the Baltic and Bothnia archipelagoes as national parks before the summer cottages take over or something otherwise happens to spoil their natural features. This movement might be the sort of thing that could be made to fit in with a broad plan for refuge expansion.

Conflicts of human interests may be expected to extend across the whole waterfowl picture. They extend from fundamental uses of the wetland biotopes through the problems of crop damage resulting from activities of waterfowl, and on up into the rights of the public interested in nature and into questions as to the hunters' share of the harvestable birds. In anything so complex and interlinked with what man wants and does, it is hardly possible for any one person or group or faction to be wholly satisfied with any solutions proposed. It may be a truism to say that the problems are those requiring give and take and some consideration of philosophies on other than a what-is-in-it-for-me basis.

Flatly, no one should expect any easy and cheap answers to the problems of waterfowl management in Scandinavia any more than in North America. Anything more than simply letting the birds take care of themselves as best they can, in the face of drainage and other forms of habitat impoverishment, weather emergencies, the oil death, and overharvesting, must call for something positive and something in the way of dedicated cooperation.

Wherever problems may relate to migratory waterfowl, there we may expect repeated tests of human abilities to seek be-

yond the narrowly and immediately practical, repeated tests of good thinking, good intentions, and good faith. With all of the boundaries that are so often involved, intelligent solutions must also call for a high order of constructive politics. The challenge of meeting these problems is not one just for the birds or for the Scandinavians. It takes us all in, even if only in principle, if only as an exercise or an example of peoples getting along with each other in matters that must be handled on more than a local scale. It is nothing for which to demand hard bargains that do not work for the benefit of the basic resources.

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# SOME OBSERVATIONS ON FOOD HABITS AND BEHAVIOR OF THE AFRICAN ELEPHANT

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Preliminary investigations of the African elephant (*Loxodonta africana*) in 1957 indicated that an unusually high density of elephants occurred on the savanna lands in the Murchison Falls National Park region of Uganda (Buechner, *et al.*, unpub. ms.). Since there are exceptionally few elephant populations from which meaningful samples can be obtained for study purposes, it was evident that the Murchison population provided an exceptional opportunity for obtaining population data and studying related phenomena concerning this species. Consequently the original study was expanded into a long-range project on the ecology, reproduction, and population phenomena of the African elephant, which includes the following objectives: (1) to determine distribution, abundance, and migration; (2) to study the morphology and replacement rates of molariform teeth for developing valid techniques in determining age of the wild elephant; (3) to ascertain annual distribution of breeding and parturition dates; (4) to estimate natality and mortality rates; (5) to extend studies which have been reported on the physiology and endocrinology of reproduction in the elephant; and (6) to study food habits, the role of fires and elephants to vegetational changes, and the relation of vegetational changes to population density. To help fulfill these objectives, 127 elephants were collected from Bunyoro and Toro districts of Uganda between July 14, 1958, and June 4, 1959. The animals were taken from two large populations, outside of national parks, and primarily from localities where they were being killed on control operations by the Game and Fisheries Department of Uganda.

This particular study is part of the long-range project and was conducted primarily to determine the food habits of elephants collected during and soon after the dry season from the Murchison population, and to record observations on behavior which appeared to be related to the elephant's food habits. Supplementary observations of food habits were recorded from other areas at various times.

Seventy-one of the elephants were used in this study and were collected between December 22, 1958, and May 7, 1959, from an area of approximately 360 sq. mi. east of Lake Albert and south of Murchison Falls National Park in Bunyoro District; 14 were taken on Butiaba Flats and 57 were collected east of the escarpment (Fig. 1; also see Eggeling (1947:21) for a description of this area and the Budongo Forest which extends onto the southwest part of the area).

Scientific names of trees and shrubs, and most of their common and local names, follow Eggeling (1958); those of other plants are from various sources including local lists (a complete guide to flora does not exist).

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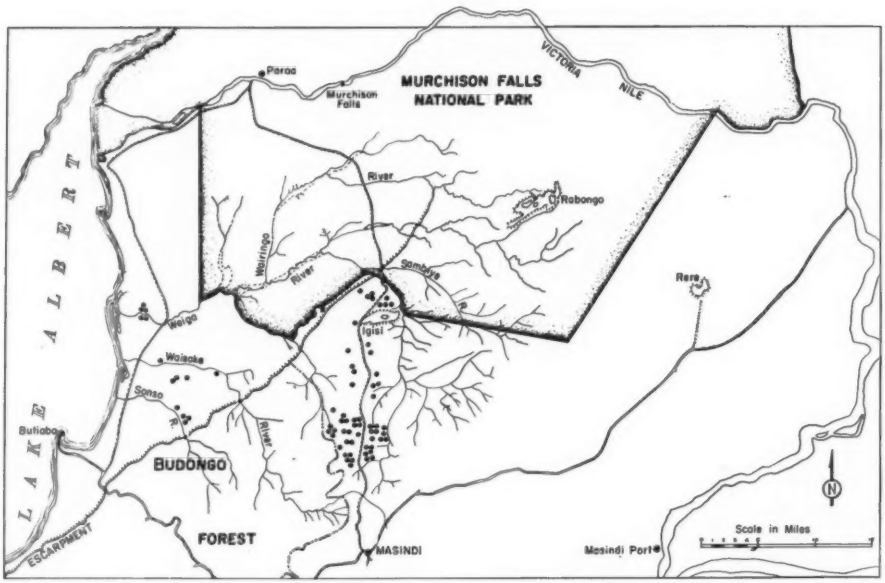


FIG. 1. Locations of 71 African elephants collected for this study. Each dot represents one elephant.

ing funds were provided by the Game and Fisheries Department of Uganda.

## HABITAT

*Description of area.*—Lake Albert Marsh (elevation about 2,035 ft.) is at the east edge of the lake, near the mouths of the Waisoke and Weiga Rivers. East of the marsh is a nearly flat area about 4 to 8 mi. wide known as Butiaba Flats. This is a semi-arid savanna dominated by secondary pyrophytic vegetation. Shantz and Turner (1958:139) state that on the slopes of the escarpment at the south end of Butiaba Flats, "Intensive annual burning undoubtedly destroys the larger non-sucker forming trees and selects for smaller, rapid-growing sucker-forming types . . . ." Desert date (*Balanites aegyptiaca*), desert thorn (*Acacia* spp., probably mostly *A. hockii*), tamarind (*Tamarindus indica*), candelabra (*Euphorbia candelabrum*), *Harrisonia abyssinica*, *Commiphora abyssinica* var. *simplicifolia*, *Aloe* sp., and *Sansevieria* sp. are common locally or widely scattered. The sausage tree (*Kigelia aethiopica*) grows commonly along watercourses with other trees and shrubs, providing shade and cover for elephants.

At the east edge of Butiaba Flats the land rises steeply for over 1,000 ft. to the top of an escarpment—the east side of the Albert Rift. The land east and above the escarpment is undulating and occurs on the gentle upper slopes of the watershed where the Weiga, Waisoke, and Sonso Rivers originate. These rivers flow westward, across Butiaba Flats, and into Lake Albert. The vegetation above the escarpment and north of Budongo Forest consists of extensive grasslands on which scattered trees and numerous woodlands occur, many of them less than 10 a. in size. Most of the grasslands are dominated by dense stands of thatching grass (*Hyparrhenia dissoluta* and *H. filipendula*). *Andropogon gayanus*, which attains a height of 12 ft., and *Loudetia arundinacea* are mixed with thatching grass on the hills. Elephant grass (*Pennisetum purpureum*) and guinea grass (*Panicum maximum*) are dominant in low areas and along watercourses. Other common grasses include *Setaria sphacelata*, *S. longiseta*, *Brachiaria brizantha*, *Paspalum commersonii*, *Imperata cylindrica*, *Heteropogon contortus*, and *Sporobolus* sp. Generally the growth of grass is less luxuriant near the escarpment where the soil is poorer and the climate drier than it is further east (Eggeling, 1947: 34). The two most common trees of the grasslands are the small *Combretum binderanum*, which occurs in nearly thicket-like stands on some sites, and the larger *Terminalia velutina*, which attains a height of about 35 ft. A few desert date occur near the escarpment, and black-plum (*Vitex doniana*) is scattered locally through the grasslands. Throughout most of the grasslands there are termite (*Bellicosus aurivillii*) mounds.

The woodlands on the area above the escarpment are in various stages of development or

recession; these stages are very similar to three chief types of forest described by Eggeling (1947: 57) for Budongo Forest. The presence of *Maesopsis eminii, Olea welwitschii, Caloncoba schweinfurthii, Albizia coriaria,* and *Dombeya mukole* in two-storied woodlands, which contain trees characterized by relatively low height-class (70 to 100 ft.) and small diameters, few or no buttresses, scarcity of mosses and lichens, and many small climbers, indicate pioneering or colonizing woodlands of early seral stage. An intermediate and rich woodland of many seral species includes *Alstonia congensis, Khaya anthotheca, Entandrophragma cylindricum, E. utile,* and several species of *Chrysophyllum* and *Celtis.* These trees are recognizable in three or four stories, vary in height up to about 120 ft., and have relatively large diameters and well-developed buttresses. Many vascular epiphytes occur on the trees. Near Rabongo Hill, isolated woodlands represent remnants of Rabongo Forest; according to Buechner and Dawkins (unpub. ms.) these woodlands are in a recessive stage and are dominated by *Cynometra alexandri,* an indicator of climax (Eggeling, 1947: 59). At various other places on the area, tall individual forest trees with smooth trunks measuring up to about 100 ft. from ground level to crown collar provide evidence of former climax or intermediate woodlands.

*Vegetational changes on the area.*—Evidence has been recorded for some of the vegetational changes which occurred in previous years on the area north of Budongo Forest to the Victoria Nile River and west of the east boundary of the Park to Lake Albert. The magnitude and time of most of these changes are unknown.

Buechner and Dawkins (unpub. ms.) studied vegetational change in Murchison Falls National Park, and in speculating on the vegetation which occurred south of the Victoria Nile a century ago state that, ". . . it seems likely that high *Cynometra alexandri* forests were at one time more extensive, although limited to the area in the vicinity of Rabongo Hill, and that gallery forests were numerous along streams and around springs."

In discussing the occurrence and historic significance of elephant grass on the area, Eggeling (1947:36) states that, "In Uganda, pure stands of elephant grass usually indicate a man-made condition which persists, because of fire, even after man's activities have ceased. If burning can be prevented, the density of the stand diminishes, light enters, woody species regenerate and the slow process of forest formation begins." Worthington (1958:10) expresses the view that in Uganda the large areas of elephant grass were once high forest; his views support those of Thomas (1940), who believes that ". . . elephant grass should be regarded as a man-made degradation of forest." Eggeling (1947:36) points out that, "Alternatively, it is possible that at the time when the original lateritic blanket over Bunyoro eroded, elephant grass competed successfully with forest for the colonization of the freshly formed soils, and that with the aid of fire the grass has held its gains ever since."

The area north of Budongo Forest to the Victoria Nile and west of the forest to Lake Albert was closed to settlement as a Sleeping Sickness Area in about 1912, and the area has served as a game reserve since then. Assuming that the high elephant population presently on the area (Buechner, *et al.,* unpub. ms.) has developed since 1912, I infer that the greatest damage to forest vegetation by elephant should have occurred in the past 50 years. However, the widespread occurrence of old termite mounds, which are not generally constructed in forests of Bunyoro, and numerous old *Terminalia velutina* (a savanna tree) in the grasslands of the area do not support such a conclusion. Eggeling (1947:33) expresses the belief that north, northeast, and northwest of Budongo Forest elephants and fires slowed down and possibly prohibited the spread of the forest. However, he concluded (p. 38) that, "An examination of the areas of Colonizing Forest shows conclusively that within the last thirty years Budongo has spread considerably. The evidence includes the presence of relict *Terminalia velutina* and of derelict termite mounds of a grassland type well within the forest, and is confirmed by a comparison of old and present-day maps."

The high elephant population of this area is concentrated inside the Park where the animals are involved in a high rate of destructiveness to trees. The elephant uses its tusks with amazing dexterity in rending bark from trees (Fig. 2), and when trees at the edge of a forest are damaged, the exposure of the cambial layer and other living tissues to fire eventually kills many trees. Buechner and Dawkins (unpub. ms.) concluded that death of these trees allows more light to penetrate into the forest edge, permitting the invasion of grasses that carry the fire from adjacent grasslands progressively deeper into the forest. Since the amount of fire destruction at the forest edge is directly related to the extent of tree damage by elephants, it appears that the elephants are destroying the forests. Actually, the elephant's depredations to trees act as a catalyst to fires, which are directly and primarily responsible for changing woodlands to grasslands. Buechner and Dawkins (unpub. ms.) state that, "It is through the basic influence of fire that vegetation in the Park south of the Victoria Nile is now primarily treeless grassland."

Shantz and Turner (1958) documented changes in vegetation which occurred in the southern part of Butiaba Flats between 1920 and 1957. They refer (p. 142) to the work of Eggeling (1947) and state that he ". . . may be correct that elephants *and* fire were responsible for the original destruction of a 'closed forest' and its replacement by open savanna and grassland on the Butiaba flats, but certainly it seems clear from the photographic evidence that fire is the most important

factor in maintaining that dis-climax today." It seems highly improbable that closed, high tropical forest (similar to Budongo Forest) would develop on Butiaba Flats even if fires and elephants were eliminated since the annual rainfall is now only 30 in. (Anon., 1959a).

Regardless of the comparative effects which fires and elephants had many years ago in initiating destruction of forests on Butiaba Flats or above the escarpment, most of the evidence obtained during the past 50 years indicates that fire is the dominant ecologic force inhibiting natural development and regeneration of forest communities and maintenance of extensive grasslands. It seems apparent that suppression of fires on grasslands, particularly where remnant forest and shrub species still persist, would help these species regenerate and establish extensive stands.

## FOOD HABITS

*Methods.*—Direct observations of feeding habits and food utilized by elephants were recorded in the field on every possible occasion.

The stomach and contents of each elephant was weighed in the field on a government-tested spring scale having a capacity of 600 lb. The contents were removed, the empty stomach was weighed, and the net weight of the contents was recorded. The stomach contents were then spread on the ground to a uniform thickness of about 2 in. and divided into four approximately equal parts to facilitate percentage estimates. The items in each part were identified, and the percentage occurrence of each item was estimated and recorded (Table 1). Items which were not identified in the field were preserved and identified subsequently with the aid of reference materials. The moisture content among the stomachs was conspicuously similar regardless of the amount of material in a stomach or the distance from a source of water at which an elephant was collected. The total net weight of the stomach contents was multiplied by the percentage of each item to determine its relative wet weight.

TABLE 1.—STOMACH CONTENTS OF 71 AFRICAN ELEPHANTS EXAMINED DURING A DRY SEASON IN UGANDA

| Item | Total Pounds Consumed | Percentage of 71 Elephants in Which Items Occurred |
|---|---|---|
| Mature grass[1] | 8363 | 99 |
| Young grass[1] | 1055 | 56 |
| *Combretum binderanum* (combretum) | 587 | 35 |
| *Vitex doniana* (black-plum) | 130 | 9 |
| *Afromomum* sp. (wild ginger or masasa) | tr. | 8 |
| *Stereospermum kunthianum* (mulemangundu) | 38 | 7 |
| *Sansevieria–Aloe* (sansevieria–aloe) | 184 | 6 |
| *Kigelia aethiopica* (sausage tree) | 35 | 4 |
| *Trichilia roka* (makaku) | 8 | 3 |
| *Piliostigma thonningii* (camel's foot leaf tree or mugali) | tr. | 3 |
| *Harrisonia abyssinica* | 160 | 1 |
| *Portulacaeae* (purslane) | 1 | 1 |
| *Cissus quadrangularis* (ivy) | 1 | 1 |
| *Balanites aegyptiaca* (desert date) | tr. | 1 |
| *Terminalia velutina* (terminalia) | tr. | 1 |
| *Khaya grandifoliola* (African mahogany) | tr. | 1 |
| *Entandrophragma* sp. (Budongo mahogany or muyovu) | tr. | 1 |
| *Ficus* sp. (fig tree) | tr. | 1 |
| *Hoslundia opposita* (nkibibi) | tr. | 1 |
| *Tinnea aethiopica* (kanyahira) | tr. | 1 |
| Sticks (2.5, 3, 4.25 in. long) | tr. | 1 |
| Stones (35, 28, 25, 20 mm. in diam.) | tr. | 1 |
| Unidentified woody materials | 60 | 30 |

[1] Includes *Hyparrhenia dissoluta, H. filipendula, Pennesetum purpureum, Panicum maximum,* and probably *Heteropogon contortus, Brachiaria brizantha,* and *Sporobolus* sp.

The total wet weight and the percentage occurrence of each food item from 71 elephant stomachs are presented in Table 1. Items weighing less than a pound are recorded as traces.

The droppings of elephants provided an exceptionally good source for identifying food materials utilized, since the bolus or dropping contains a relatively large percentage of undigested food material (Benedict, 1936:195). Freshly browsed food plants, with tracks and droppings nearby, were used occasionally as indicators of foods utilized.

*Grass as elephant food.*—Grasses were the most important foods of the 71 elephants collected. One or more species of grass occurred in 70 stomachs (99 percent) and comprised from 25 to 100 percent of the stomach contents by weight. The stomachs contained 9,418 lb. of grass (Table 1), or an average of about 135 lb. each. Thatching grass was eaten more frequently and in larger quantities than any other grass. Elephant grass and guinea grass were eaten occasionally; some stomachs appeared to have speargrass (*Heteropogon contortus*), palisade grass (*Brachiaria brizantha*), and rush grass (*Sporobolus* sp.), but these three grasses were not positively identified among the stomach contents. Although cotton grass (*Imperata cylindrica*) was common on the area, I found no evidence of its utilization by elephants. The one elephant which had no grass in its stomach, an 8,300-lb. (rounded to units of 25) bull shot April 15, 1959, on Butiaba Flats, had a trunk about 2 ft. shorter than other bulls of its size. Apparently its trunk had been severed by a snare which probably prevented the animal from reaching the relatively short grass available at that time. Leaves and twigs of a shrub (*Harrisonia abyssinica*) growing abundantly on the nearby plain comprised 98 percent of the food materials in its stomach; the other 2 percent consisted of pieces from the fruit coat of the sausage tree.

The exact proportions of grasslands and forest which comprise optimum range for the African elephant have not yet been determined. However, the importance of grass as a food suggests that maintenance of relatively large areas in grassland in the Murchison Falls National Park region may be highly significant to the high population of elephants which the area currently supports.

*Tree and shrub foods utilized by elephants.*—Although it is widely recognized that the activities of elephants are not regularly nocturnal, diurnal, or crepuscular, they apparently adjust the time of their activities to different circumstances. The elephants above the escarpment frequently retired from savannas into woodlands soon after sunrise, and usually started coming out of woodlands late in the afternoon. On 15 of 32 trips I made into this area, elephants were shot during the first hour after sunrise while they were feeding in grasslands near woodlands. On four of these occasions the elephants were disappearing into woodlands when they were first seen, and on three occasions I followed herds into woodlands to make collections. Elephants were seen on savannas at various times of the day on 13 trips, and I shot them on 4 occasions after sunset as they were coming out of woodlands.

During a rainstorm on March 2, 1959, I was following close behind a bull in a small woodland when I heard elephants grunting and screaming in another woodland nearby. Three different herds of elephants were heard in woodlands on January 22, 1959, at 6:10 p.m. while I was approaching a fourth herd which was feeding at the edge of a woodland. Woodlands above the escarpment during the dry season invariably showed evidence of recent occupancy by elephants. Recently used trails extended in practically all directions, fresh droppings were encountered frequently, small trees and shrubs were broken down occasionally, and in several woodlands the unmistakable scent of elephants impregnated the quiet air.

On March 18, 1959, I was following close beside a band of about 60 elephants in a woodland attempting to collect one of the animals. At least three different indi-

FIG. 2. Bark of *Terminalia velutina* damaged from 3 to 12 ft. above ground by elephants, near Weiga River, Murchison Falls National Park.

viduals were observed at less than 20 yd. breaking down or damaging saplings about 12 to 25 ft. in height. It appeared that these animals were trying to rid themselves of ectoparasites by rubbing their heads, particularly the base of their tusks where ticks tend to concentrate, on the saplings. The vertical head movements, with tusks generally straddling or close to the saplings, resulted in many broken limbs and frequently a broken trunk of the saplings. During these "bashing" operations no part of the saplings was eaten. It appeared that *Lonchocarpus laxiflorus* was damaged more frequently than other species. This observation suggests: (1) that elephants do not damage young trees for feeding purposes only, and (2) why it is commonly and erroneously believed that elephants "feed" non-selectively on all young trees of certain size classes.

Although elephants spent considerable time in woodlands, trees and shrubs provided a low percentage of their food. Only 10 percent or 1,018 lb. of the total food material in the 71 stomachs consisted of leaves, twigs, and fruit of trees and shrubs (Table 1). Leaves and twigs from *Combretum binderanum*, which occurred in 35 percent of the stomachs, were eaten more frequently than any other woody food. Elephants appeared to prefer combretum about 4 to 15 ft. in height; these young trees grew profusely on lands where annual fires had obviously occurred regularly for many years (Fig. 3). On five occasions elephants were collected while feeding from combretum of this size class, and on

FIG. 3. A favorite feeding site for elephants northeast of Budongo Forest and south of Murchison Falls National Park. Five elephants were collected and four herds were seen feeding on this burned-over area dominated by grass and *Combretum binderanum*.

numerous other occasions they were seen feeding on both grass and combretum where the latter species was in this size class. Leaves, twigs, and many mature fruits of black-plum were found in 7, or 9 percent, of the stomachs; the stomach of a 5,840-lb. female collected on December 29, 1958, contained over a gallon of ripe black-plums. Small quantities of leaves and twigs from *Stereospermum kunthianum*, which is a common tree where these elephants were collected, occurred in 7 percent of the stomachs. Pieces from the fibrous fruit coat of the sausage tree were found in three stomachs, leaves from the makaku tree (*Trichilia roka*) were identified in two stomachs, and several leaves from the camel's foot leaf tree (*Piliostigma thonningii*) occurred in two stomachs. A bull which fed on the shrub *Harrisonia abyssinica* has been discussed above. Although fruits of desert date were found in only 1 of the 71 stomachs, it was noted that 3 elephants shot near the Waisoke River on Butiaba Flats between December 17 and 19, 1958 (before stomach contents were analyzed), had fed extensively on the fruits of this tree; one stomach contained over a thousand fruits. A few leaves of *Terminalia velutina* occurred in only one stomach. This is a very common tree which sustains extensive bark damage by elephants, whereas *Balanites aegyptiaca* receives very little or no bark damage from elephants. Since both trees are common on the area, it appears that the elephants damage ter-

FIG. 4. Aloe near Weiga River, Butiaba Flats.

minalia selectively (Fig. 2). A few green leaves and a fruit of African mahogany (*Khaya grandifoliola*) were found in one stomach, several leaves from Budongo mahogany (*Entandrophragma* sp.) were eaten by one elephant, and part of the fruit from a fig tree (*Ficus* sp.) occurred in one stomach. Unidentified woody materials which totaled 60 lb. occurred in 30 percent of the stomachs; combretum probably comprised a high percentage of this material.

On the basis of direct field observations and the contents of the stomachs examined, it must be concluded that the elephants used the woodlands primarily for daytime concealment and shade, but not as a principal source of food.

*Forbs and miscellaneous materials eaten by elephants.*—Herbaceous plants including sansevieria, aloe (Figs. 3 and 4), a vine, sticks, and stones comprised 2 percent of the total material in the 71 stomachs (Table 1). Fruits and seeds of wild ginger or masasa (*Afromomum lutealbum*) occurred in 8 percent of the 71 stomachs. Evidently these fruits are very palatable to the elephant, since the fruit grows close to the ground and is frequently completely hidden by surrounding vegetation.

Five bulls collected near the Weiga River, Butiaba Flats, in February had all eaten from the fleshy and succulent basal leaves of aloe (Figs. 4 and 5) and the leaves of sansevieria. The stomach contents from four of these bulls were analyzed; leaf material from these two plants comprised from 10 to 30 percent of the total weight of food in their stomachs. Aloe and sansevieria occur on the plain between the escarpment and the marsh, growing most abundantly at the east edge of Lake Albert Marsh and close to the rivers. Here the elephants fed on these plants during the night and generally returned to the tall, dense vegetation of the marsh very early in the morning. It is widely believed that elephants chew the leaves of aloe and sansevieria for moisture, spitting out the masticated fiber in balls. A. M. H. Henley, formerly an employee of the Game and Fisheries Department of Uganda, informed me that he had witnessed elephants utilizing these plants on Butiaba Flats in this manner. Also, George A. Petrides, who conducted various big game studies in East Africa as a Fulbright Research Scholar, informed me that these discarded sanse-

FIG. 5. Elephants fed from this aloe near the Weiga River during the night of February 20, 1959.

vieria "chews" were common in the Northern Frontier District of Kenya where it is very dry. It appeared that the leaf material eaten by the four Weiga River bulls had not been chewed more than the other food materials in their stomachs, and at the many sites which I observed on Butiaba Flats where elephants had fed on these plants, I found no masticated fibrous balls that suggested this type of feeding. Since there was no shortage of water in the large marsh bordering Lake Albert and the area close to the Weiga River, there was no necessity for these bulls to eat the aloe and sansevieria for the moisture only.

Among the 71 stomachs, each of the following plants was represented once by small quantities of leaves and stems: purslane or Portulacaeae, ivy (*Cissus quadrangularis*), nkibibi (*Hoslundia opposita*), and kanyahira (*Tinnea aethiopica*). The stomach of an adult female which weighed 5,890 lb. and was shot in a woodland on March 12, 1959, contained three dry sticks which were 2.5, 3.0, and 4.25 in. long and ½-in. in diameter. An adult female which weighed 7,770 lbs. and was collected on March 19, 1959, had four stones in her stomach; they measured 20, 25, 28, and 35 mm. in diameter. It is a common belief among natives living in elephant country of Uganda that the elephants accidentally suck stones into their trunks when they are drinking and then deliver both stones and water into their mouths.

*Other foods and behavior related to feeding.*—In addition to data obtained on elephants near Murchison Falls National Park, observations were recorded on the food habits of elephants in Toro District, southwest Uganda, between August and November 1958. The fruits of the borassus palm (*Borassus aethiopum*) and the leaves and twigs (including spines) of the desert thorn (probably *Acacia sieberiana*) are highly favored food items for elephants. Eleven seeds of the borassus palm were counted in one dropping examined near the Nyakabisu River at the west edge of Semliki Plain.

Cotton has a special attraction for elephants, particularly when the bolls are starting to open. Unfortunately, where cotton fields are available to elephants, depredations occur frequently, and control of the marauding animals is necessary. During November 1958, William O. Pridham, District Ranger in Toro District, received complaints from natives of elephants raiding cotton fields at night in the Mubuku River area near Kilembe Mines and the border of Queen Elizabeth Park. From November 22 to 28 I accompanied Mr. Pridham on a safari to this area, where we succeeded in collecting seven elephants. The first one, an 8,820-lb. bull, was shot at 11:00 p.m. while feeding with a band of 11 large-appearing elephants in a cotton field where extensive damage to cotton had occurred. The following afternoon at 5:00 p.m. we started searching the Park boundary for elephants and trails leading toward the cotton fields. At 6:30 p.m. a band of five elephants was seen about ¼ mi. inside the Park boundary. They were headed out of the Park; hence we hid and watched them until 7:40 p.m., by which time they had crossed the railroad track which forms the Park boundary and were shuffling toward the cotton fields. At this time we shot a 6,240-lb. bull from the herd; the remaining four elephants bolted and ran back into the Park.

On the next afternoon, November 24, we returned to the same site at the Park boundary to watch for other elephants that might leave the Park and start for the cotton fields. At 5:50 p.m. a herd of nine elephants was feeding and meandering toward the boundary, precisely over the same route taken by the herd on the previous day. This herd consisted of three adults (about 5,000 to 8,000 lb.), three sub-adults (about 3,000 to 5,000 lb.), two intermediates (about 1,000 to 3,000 lb.), and a calf (less than a year old). At 6:30 p.m. they reached the railroad track exactly where the herd had crossed the previous night; a sub-adult male or young bull was acting as leader and was followed closely by a very large cow that was much more cautious and wary than the young bull.

Just as the young bull stepped over the first rail, both he and the large female caught the scent remaining from the bull shot during the previous day. Both animals turned immediately and retreated with the herd into a thicket about 25 yd. from the track. The young bull was first to return to the track and attempt to cross the second time; the large female followed but very cautiously and farther behind than the first time. The entire herd advanced slowly, several steps at a time. They were tense, with ears and tails lifted slightly and held rigidly, trunks lifted and testing the air continuously, and each step was deliberately slow. The young bull and large cow walked parallel to the track for about 20 yd. as though searching for another place to cross, but they returned to the original crossing where the young bull again started to lead the herd across the track. Before stepping across the first rail, he paused and tested the air from what appeared to be a very tense and strained position. Then he stepped across the first rail, stopped briefly, and walked slowly but directly to the site of the dead bull. The large cow followed in much the same manner, but she was even more cautious in her actions and appeared more reluctant to approach the site of the dead bull. Within 6 more minutes the rest of the herd crossed at the same place. After the last elephant was clear of the track, the herd began to relax. Tails and ears hung down loosely, there was much defecating and micturating, and most of the animals "sniffed" the ground where the bull was shot the previous day. At 6:45 p.m., just as the herd was starting to leave, the young bull (4,570 lb.) and the large cow (8,500 lb.) were shot. The other seven elephants turned immediately and recrossed the tracks without hesitancy and disappeared into the dusk and the thickets of the Park.

During the last week in April 1959, I examined more than 50 sets of droppings from elephants in the Kibale Forest and along the Kazinga Channel near Queen Elizabeth Park; all of these droppings contained at least 90 percent grass. Five sets of droppings examined near the Mpanga River, deep within the Kibale Forest where grass was scarce and woody foods were abundant, consisted of 98 percent grass. Those examined along the Kazinga Channel showed that grass was eaten in greatest volume and that desert thorn was second in volume consumed. Also along the Kazinga Channel, elephants fed extensively on a medium-sized shrub (*Grewia similis*); on numerous occasions I found plants that had been pulled from the ground. The natives who believe that elephants pull out these plants to eat their roots are probably correct; however, I believe it is possible that elephants pull the plants out by trying to browse more than the terminal tips. Brooks (1957) reports utilization of *G. similis* and states that along the eroded banks of the channel "Most plants are stunted owing to overbrowsing by elephant." The ripe fruits (and possibly the young tips) of *Capparis tomentosa*, one of the dominant shrubs along the Kazinga Channel, are eaten extensively by elephants. *Albizia coriaria*, *Tamarindus indica*, and both *Cissus quadrangularis* and *C. rotundifolia* provide food for elephants in the vicinity of Kazinga Channel.

The stomach of an 8,900-lb. bull shot on May 1, 1959, contained 85 percent papyrus (*Cyperus papyrus*) and 15 percent grass. Before shooting this bull from a large papyrus swamp bordering the Chambura River and Queen Elizabeth Park, I saw it skillfully select the newly grown tops of the papyrus and reject the old tops. This papyrus swamp, as well as one bordering the Victoria Nile below Murchison Falls, showed very extensive utilization by elephants. Evidently papyrus is at least a favored food item to elephants in localized areas during certain seasons.

*Time of feeding and amount of stomach contents.*—The weight of stomach contents, the percentage of stomach weights to live weights, and the time of collection for 54 elephants are presented in Table 2. (The food analyses of these elephants, except Groups 5, 14, and 17, are included in Table 1.)

The nine fullest stomachs (those weighing 4.9 to 6.0 percent of their live weights —see Groups 6, 7, 8, 11, and 16) were from elephants collected between 7:40 and 10:15 a.m. Other elephants which were collected early (Groups 1, 4, 13, and 15) also contained relatively full stomachs. It is interpreted here that these elephants with relatively large amounts of food in their stomachs in the morning had fed during the night and early morning; Benedict (1936:191) reports the minimum elapsed time before items fed to a captive Asiatic elephant appeared in feces to vary from 21 to 30 hr.

Numerous evidence was obtained indicating that elephants fed at night. Before sunrise (6:20 a.m.) on February 18, 1959, fresh elephant droppings and tracks near partly eaten bushes of sansevieria and aloe on Butiaba Flats indicated that elephants had been feeding on these plants during the night; the tracks were followed until 7:30 a.m. when two large bulls were collected (Group 2) as the herd of five bulls was retiring into Lake Albert Marsh. On the following morning, three bulls (Group 3) were tracked down and collected within a mile of the Group 2 collections, under practically the same conditions. On March 26, 1959, at 7:15 p.m. John B. Heppes and I saw 19 large elephants (probably all bulls) by moonlight feeding and meandering eastward from Lake Albert Marsh between the Weiga and Waisoke Rivers; backtracking indicated that these animals had been in the marsh during the day. (Also note discussion above, under *Other foods and behavior related to feeding*, concerning night feeding in cotton fields.)

Some elephants which were collected early in the day (Groups 2, 3, 5, 9, 10, 12, and 14) had relatively small amounts in their stomachs; most of them were feeding when they were collected (see discussion of Group 5 below under *Family groups*). Nearly all elephants collected in the afternoon (Groups 17, 18, and 19) had relatively small amounts of food in their stomachs.

These observations indicate that feeding occurred most frequently during early morning, but some elephants fed at various times of the day and night. Benedict (1936:67) concluded that the only time when the Asiatic circus elephant is not eating during the 24 hours when hay is available is when the animal is lying down, and since the period of lying is relatively short, it is eating almost constantly. Benedict (1936:67) also states that, "The wild elephant munches food a good part of the twenty-four hours." Direct observations which I made of wild African elephants indicated that they were searching almost continually for food with their trunks, but very frequently it appeared that only very special items were selected and eaten. At other times it appeared that the animals were engaged primarily in feeding and consumed large quantities of food in relatively short periods of time. Collectively, these observations of the African elephant's food habits and its inefficient digestion (Benedict, 1936:195) indicate that its life must virtually be one continuous meal or the animal dies of starvation.

When the weights of stomach contents for the nine fullest stomachs shown in Table 2 were plotted graphically against the live weight for these elephants (Fig. 6), the points showed a linear regression. The points collectively determined a calcu-

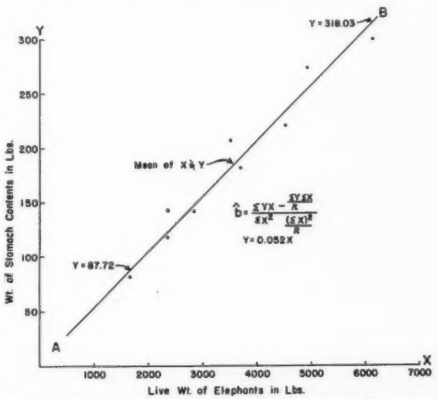


FIG. 6. Regression of $Y$ on $X$ based on observations of nine elephants having relatively full stomachs.

lated regression line *AB*, with *Y* (*Y* = wt. of stomach contents) values of 87.72 (at 1,687 *X*) and 318.03 (at 6,116 *X*). The two means intersected at *Y* (185.22) and *X* (3,553.44) (*X* = live weight of elephants).

The regression line *AB* can be considered as a moving average determined by the points among which it passes, and the best estimate of maximum weight of stomach contents (expectation value) per live weight falls on the regression line.

Six of the nine fullest stomachs (67 percent) were from females (100, 102, 103, 111, 113, and 114) and three were from males (61, 98, and 106). This proportion is almost identical to the 37 females (70 percent) and 16 males for which stomach weights are available (Table 2), suggesting similarity between sexes in maximum amounts eaten by these elephants.

## BEHAVIOR

*Effects of the dry season on movements and feeding, 1958–59.*—Soon after the dry season began in early November 1958 on Butiaba Flats, savanna-land vegetation matured and became dormant, and natives resorted to their traditional practice of starting fires wherever grass and forbs appeared dry enough to burn. At about

TABLE 2.—VOLUME OF STOMACH CONTENTS RELATED TO TIME OF COLLECTION, GROUP BEHAVIOR, AND TOTAL WEIGHT IN 19 GROUPS OF ELEPHANTS[1]

| Group No. and Time Collected | Specimen No. | Sex | Wt. of Elephant (lb.) | Stomach Contents | | Food Items in Stomach (in percentage of total contents) |
|---|---|---|---|---|---|---|
| | | | | Weight (lb.) | Percent of Live Wt. | |
| 1 | 92 | F | 5,371 | 216 | 4.0 | 97 old grass, 3 combretum |
| 7:25 a.m. | 93 | F | 4,570 | 173 | 3.8 | 95 old grass, 4 new grass, 1 combretum |
| | 94 | M | 2,633 | 86 | 3.3 | 95 old grass, 5 combretum |
| 2 | 84 | M | 9,911 | 252 | 2.5 | 70 grass, 30 sansevieria and aloe |
| 7:30 a.m. | 83 | M | 9,085 | 265 | 2.9 | 80 grass, 20 sansevieria and aloe |
| 3 | 85 | M | 7,137 | — | — | 85 grass, 15 sansevieria and aloe |
| 7:30 a.m. | 86 | M | 6,647 | 149 | 2.3 | 80 grass, 20 sansevieria and aloe |
| | 87 | M | 5,931 | 247 | 4.1 | 90 grass, 10 sansevieria and aloe |
| 4 | 107 | F | 7,744 | 325 | 4.2 | 80 old grass, 20 new grass, tr. terminalia leaves |
| 7:30 a.m. | 109 | F | 5,843 | 245 | 4.2 | 92 old grass, 8 combretum leaves and twigs |
| | 108 | F | 4,388 | 163 | 3.7 | 60 old grass, 40 combretum leaves and twigs |
| | 110 | F | 4,231 | 173 | 4.0 | 60 old grass, 40 combretum leaves and twigs |
| 5 | 54 | F | 6,122 | 18 | 0.3 | |
| 7:40 a.m. | 53 | F | 4,914 | 82 | 1.7 | (Stomach contents not analyzed; entire herd feeding in grass about 3 weeks old.) |
| | 52 | M | 3,200 | 46 | 1.4 | |
| | 51 | M | 1,805 | 59 | 3.3 | |
| | 55 | M | 1,796 | 40 | 2.2 | |
| 6 | 97 | F | 3,152 | 120 | 3.8 | 85 old grass, 15 new grass |
| 7:40 a.m. | 98 | M | 2,838 | 141 | 4.9 | 85 old grass, 15 new grass |
| | 113 | F | 6,116 | 300 | 4.9 | 92 grass, 8 combretum |
| 7 | 111 | F | 4,922 | 274 | 5.6 | 75 old grass, 25 combretum leaves and twigs |
| 7:45 a.m. | 112 | F | 2,551 | 86 | 3.4 | 97 grass (85 new, 15 old), 3 combretum |
| | 114 | F | 2,356 | 142 | 6.0 | 75 old grass, 25 combretum leaves and twigs |
| 8 | 62 | M | 4,881 | 184 | 3.8 | 75 old grass, 24 new grass, 1 unidentified |
| 8:00 a.m. | 61 | M | 4,509 | 220 | 4.9 | 75 old grass, 24 new grass, 1 unidentified |
| 9 | 63 | F | 5,095 | 149 | 2.9 | 70 grass (80 old, 20 new), 30 combretum |
| 8:00 a.m. | 64 | M | 3,247 | 110 | 3.4 | 85 grass (80 old, 20 new), 15 combretum |

this same time the elephants on Butiaba Flats began to assemble into herds for their migration upstream over the escarpment to the headwaters of the rivers. Within a month fires swept over practically all of Butiaba Flats and many of the well-drained grasslands above the escarpment. Although the vegetation on various sites did not mature and burn simultaneously, there was a continual diminution of old-growth vegetation as the dry season advanced. By the end of the dry season in late March 1959, practically all grasslands on the area were burned over at least once; some mature grass persisted in low, damp areas. By early December most of the elephants had dispersed and emigrated from the savannas on Butiaba Flats. An aerial reconnaissance over the area on December 16, 1958, revealed a herd of about 40 elephants in Lake Albert Marsh and several smaller herds close to the Weiga River and the escarpment; no elephants were seen south of the Weiga River on Butiaba Flats on this flight.

In their migrations from and back to Butiaba Flats, some elephants move through the Budongo Forest where they live temporarily in seclusion. Their feeding habits, and frequently their mere presence, inter-

TABLE 2. (CONT.)—VOLUME OF STOMACH CONTENTS RELATED TO TIME OF COLLECTION, GROUP BEHAVIOR, AND TOTAL WEIGHT IN 19 GROUPS OF ELEPHANTS[1]

| Group No. and Time Collected | Specimen No. | Sex | Wt. of Elephant (lb.) | Stomach Contents | | Food Items in Stomach (in percentage of total contents) |
|---|---|---|---|---|---|---|
| | | | | Weight (lb.) | Percent of Live Wt. | |
| 10 | 65 | F | 6,324 | 249 | 3.9 | 100 grass (95 old, 5 new) |
| 8:10 a.m. | 66 | F | 4,525 | 128 | 2.8 | 99 grass (90 old, 9 new) |
| | 67 | F | 812 | 19 | 2.3 | 100 old grass |
| 11 | 101 | F | 5,868 | 247 | 4.2 | 85 old grass, 15 new grass |
| 8:30 a.m. | 100 | F | 3,693 | 182 | 4.9 | 98 old grass, 2 unidentified woody materials |
| | 103 | F | 3,502 | 206 | 5.9 | 90 old grass, 8 new grass, 2 woody materials |
| | 102 | F | 1,687 | 84 | 5.0 | 95 old grass, 4 new grass, 1 woody materials |
| 12 | 71 | F | 7,168 | 170 | 2.4 | 95 grass (95 old, 5 new), 5 mulemangundu |
| 8:45 a.m. | 72 | F | 6,151 | 130 | 2.1 | 98 grass (95 old, 5 new), 2 mulemangundu |
| 13 | 121 | M | 8,610 | 242 | 2.8 | 98 grass (90 old, 10 new), 2 unidentified |
| 8:45 a.m. | 122 | F | 6,442 | 260 | 4.0 | 60 old grass, 30 new grass, 10 mulemangundu |
| 14 | 47 | F | 6,661 | 194 | 2.9 | |
| 9:45 a.m. | 46 | F | 4,695 | 168 | 3.4 | (Stomach contents not analyzed; entire herd collected.) |
| | 45 | F | 3,369 | 106 | 3.1 | |
| | 48 | F | 685 | 16 | 2.3 | |
| 15 | 68 | F | 5,693 | 199 | 3.5 | 80 grass (75 old, 25 new), 20 combretum |
| 9:45 a.m. | 69 | F | 4,730 | 179 | 3.8 | 95 grass (90 old, 10 new), 5 combretum |
| 16 | 105 | F | 6,159 | 271 | 4.4 | 95 grass (60 old, 40 new), 5 combretum |
| 10:15 a.m. | 106 | M | 2,358 | 118 | 5.0 | 98 old grass, 2 unidentified |
| 17 | 38 | F | 5,596 | 154 | 2.8 | |
| 3:00 p.m. | 37 | F | 4,888 | 90 | 1.8 | (Stomach contents not analyzed; part of herd collected.) |
| | 36 | M | 4,153 | 88 | 2.1 | |
| | 39 | F | 3,348 | 62 | 1.9 | |
| 18 | 117 | F | 5,826 | 128 | 2.2 | 99 grass, 1 unidentified woody materials |
| 5:00 p.m. | 118 | M | 3,409 | 69 | 2.0 | 98 grass, 2 unidentified woody materials |
| 19 | 81 | F | 4,192 | 143 | 3.4 | 99 old grass |
| 6:45 p.m. | 82 | F | 1,757 | 47 | 2.7 | 99 old grass |

[1] All stomach contents (except those from No. 85 and Groups 5, 14, and 17) are from elephants included in Table 1.

fere with logging operations, and as a consequence many animals are shot by officials of the Game and Fisheries Department on control assignments. In the calendar year 1957, 24 percent of the 912 elephants shot on control operations in Uganda were recorded at Masindi (Anon., 1959b); most of them were shot in Budongo Forest.

Throughout the dry season of 1958–59, elephants were concentrated in the interspersed grasslands and woodlands (which remained unburned) above the escarpment at the headwaters of the Weiga and Waisoke Rivers and between Budongo Forest and the Park boundary. This is presently ideal range for elephants. Between December 22, 1958, and March 21, 1959, I made 32 trips to this area, saw from 1 to 35 elephants on all except two of these trips, and shot 57 elephants. Each morning that I visited the area during this period there were many fresh droppings on the road and many freshly made trails crossing the road, attesting further to the presence of many elephants.

With the onset of the rainy season in late March 1959, many of the elephants above the escarpment were congregating into large herds preparatory to their emigration from the area. Between March 18 and 23, I saw four herds on the area above the escarpment, each consisting of at least 100 elephants; all were traveling westward toward Butiaba Flats. On March 24, 1959, John B. Heppes saw three herds totaling 189 elephants migrating down the banks of Waisoke River on Butiaba Flats. The following day I saw nearly 400 elephants feeding close to the river and traveling downstream. Although we had made biweekly safaris to Butiaba Flats searching for elephants after January 6, 1959, and conducted an aerial reconnaissance over this area on February 26, 1959, these were the first elephants that we recorded between the Sonso and Weiga Rivers on Butiaba Flats since December 10, 1958. By mid-April, it appeared that the migration of elephants to Butiaba Flats had ended, very few elephants were seen above the escarpment, and the population numbers on Butiaba Flats were about as high as those preceding the dry season.

Direct field observations, and the distribution records of elephants obtained by aerial counts conducted in October 1958 and February 1959 (Buechner, *et al.*, unpub. ms.), indicated that some elephants showed a strong tendency to congregate during the dry season in Lake Albert Marsh and along the south banks of the Victoria Nile River below Murchison Falls. An aerial count conducted during the wet season in May 1959 showed very few elephants at these locations. It was evident from ground observations made at these permanent water supplies that the concentration of elephants during the dry season resulted in overutilization of some food plants and that the kinds of foods available near these sites were limited, particularly in Lake Albert Marsh. Soon after the rainy season began, water became available throughout most of the elephants' range, and they quickly dispersed from Lake Albert and the Victoria Nile to the better and more extensive food supplies on the open savannas. In some cases these migrations were probably many miles in length; in others they were relatively short. I believe this water–dry season relationship is very important in governing some of the food habits and migratory behavior of the elephant in Uganda.

*Family groups.*—On 19 occasions from 2 to 5 elephants were collected at one site from a single herd. These 19 groups, totaling 54 animals, were studied to determine whether: (1) these groups represented closely related or family units; (2) the food habits and behavior of individuals within each group were similar; and (3) these closely related or family groups were the basic units governing behavior of the elephant population. The sex, total weight, weight of stomach contents obtained at the time of dissection, and the percentage occurrence of the most prevalent food items which occurred in each stomach are presented for most of these animals in Table 2. Each group was collected on a different day between 7:25 a.m. and 6:45

p.m. local time. The groups are arranged from the earliest to the latest time of day collected (Table 2) to show possible relations between time of day during which elephants were collected to the volume of food in their stomachs; individuals within a group are arranged in descending order of total body weight to further facilitate comparisons.

At the time of collection, certain elephants within a group frequently disclosed behavior which indicated that these groups were closely related or family units. This behavior was most conspicuous among females and individuals in groups of at least four animals. The individuals of Group 5 were notable in this respect. They were part of a herd comprising at least 25 elephants which was encountered before daylight on December 31, 1958. The animals were feeding on green grass about knee-height on a savanna which was burned over about 3 weeks previously, on December 5. The abundance of fresh droppings and recently made elephant tracks indicated that this area had been visited frequently and recently by elephants. Evidently the new grass was very attractive and palatable, but direct observations of this herd, plus similar observations for Groups 6, 8, and 16, suggested that the animals did not prefer to remain very long on such areas. They moved continually while feeding and appeared restless and unusually vigilant. When the same animals encountered stands of tall, mature grass or woodlands they appeared to relax, moved more slowly, and even stopped frequently in their meanderings. This difference in behavior gave an impression of security and of protective concealment to the elephants while they fed in the tall vegetation, and it probably affected the proportions of mature and young grass which the elephants ate (see Table 1). By 7:30 a.m. the herd was leaving the burned-over area and entering tall, mature grass, mostly *Hyparrhenia dissoluta*. The animals reorganized into three rather distinct groups; five individuals (Group 5) moved farthest into the mature grass and were feeding upon it at 7:40 a.m. when the first three individuals (51, 52, and 53) were collected. At the sound of shooting, the other two groups immediately reassembled and ran out of sight, but the two remaining individuals of Group 5 (54 and 55) refused to leave. The behavior of No. 54, which proved to be a large old cow, indicated that she was the mother of No. 55, a young male (1,800 lb.) that stayed close beside the large cow for 40 minutes while she defended two of the dead elephants. The cow was furious. She trumpeted, screamed, "pawed" the ground, and tried alternately to lift the two dead animals with her tusks or bury them with debris gathered with her trunk. On four occasions she made short, vicious charges in the direction from which the shooting occurred. Shooting above her head and into the ground close to her feet failed to drive her from the dead elephants, and at 8:20 a.m. both animals were shot. On the basis of the maternal and defensive behavior of the large cow (54) to the two dead elephants, it was concluded that she was their mother. Examination of these two dead animals showed that one (52) was a small male and the other (53) was a medium-sized, lactating female. Since No. 51 was an animal of nursing size (1,810 lb.) which remained close to the medium-sized female while the group was observed feeding, it was further concluded that she (53) was the mother of No. 51. These family relationships are shown in Fig. 7.

The behavior of individuals in Group 14 was also notable in revealing the close relationship of elephants within the group. On December 5, 1958, a male elephant (No. 35) weighing 6,100 lb. was collected from a group of five animals. A large female in the group immediately defended the dead male, trumpeted, screamed, and made three silent but vicious charges in the direction from which the shooting occurred. The protection provided by a large termite mound, tall grass, and a strong wind prevented the necessity of shooting her. On three occasions she knelt beside the dead male and attempted to raise him with her

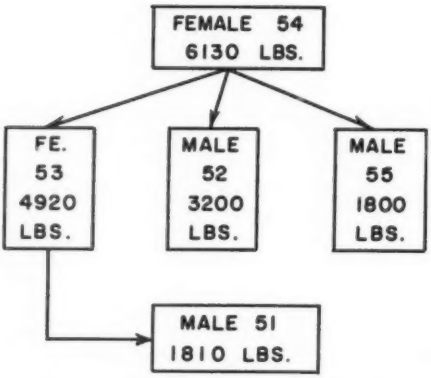


FIG. 7. Family relationships of Group 5.

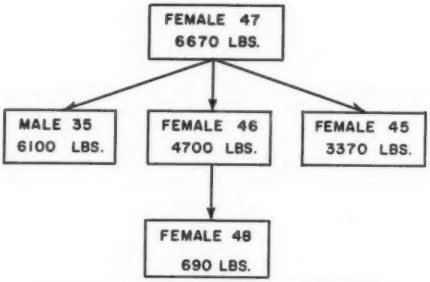


FIG. 8. Family relationships of Group 14.

tusks; failing in these attempts, she placed both front feet on the dead male, cocked her ears, and extended her trunk sinuously toward the scene of shooting — evidently she was trying to locate her enemy by smell or sight. Eventually the other three survivors of the group were stimulated to depart by shooting over them, and the large female followed. On December 22, 1958, the remaining four animals of this group were encountered within ½-mi. of the site where No. 35 was shot on December 5. Two females weighing 3,370 lb. (No. 45) and 4,700 lb. (No. 46) were shot in close succession, provoking the same behavior from the large female (No. 47) which she had exhibited on December 5. However, conditions at the second site required shooting the old female as well as the calf (No. 48) which comprised the last member of this group. Post mortem examination of these animals showed that No. 45 had not yet bred, No. 46 which was lactating freely and had an udder weighing 19 lb. was evidently the mother of the calf (No. 48), and the large cow (No. 47) had given birth to calves but was not lactating or pregnant at the time of collection. On the basis of behavior and the examinations, the family relationships shown in Fig. 8 were deduced. (Further evidence based on morphological characteristics which indicated close relationships between individuals in some of these groups will be included in a future publication.)

*Family groups as feeding units.*—The data in Table 2 show that the kinds and amount of food (considering individual size) utilized by the elephants within a group are conspicuously similar. However, this relationship is not apparent among groups, indicating that feeding was on a group basis.

The stomach contents of the five elephants in Group 5 were exceptionally low in volume, weighing from 18 to 82 lb. Although their stomach contents were not analyzed, it was noted that young grass comprised most of the food taken, a small volume of grass occurred in each stomach, and the proportions of young to mature grass among individuals appeared similar. Evidently each elephant in this group had fed for about the same length of time on approximately the same kinds of food; a similar pattern of feeding is evident for each group shown in Table 2, indicating further that feeding was based on group behavior.

*Units governing population behavior.*—In addition to the data presented in Table 2 and the related observations on family organization and feeding behavior of groups, field observations were recorded which suggested that these groups were the basic units governing behavior of the elephant population. Tennent (1867:45) discussed an Asiatic elephant herd nearly a century ago and stated that, "A *herd* of elephants is a family, not a group whom accident or attachment may have induced to associate

together." However, neither he nor subsequent writers have claimed that the elephant herd is a basic unit of population behavior.

On March 5, 1959, at 7:45 a.m. a band of 15 elephants was observed feeding and walking very slowly down the middle of a wooded valley. A second band of nine elephants was approaching from the opposite side of the valley; the bands did not detect each other's presence until 7:55 a.m. Their meeting was casual and amicable. Some individuals paused briefly, lifted their trunks slightly, then relaxed and continued eating and meandering down the valley. In less than 5 minutes all of the elephants had intermingled and were feeding and moving together as a single herd. They continued down the valley until 9:20 a.m. when a small male (1,600 lb.) was collected. In an amazingly short time, the other animals reorganized into two groups; one band of 14 individuals ran down the valley, the other band of 9 individuals departed on a diverging course for the opposite side of the valley. It was apparent, by the composition of each band, that the animals had re-formed into their original groups.

On March 11, 1959, a band of 24 elephants was observed converging upon 11 elephants on a savanna 2 mi. south of the Park boundary. Their behavior upon meeting was very similar to the behavior of the elephants in the two groups observed on March 5, except that both bands were traveling rather fast and pausing to eat only infrequently. I was stationed with my assistant in a small clump of combretum about ¼-mi. directly downwind from the approaching herd. Luckily the herd of 35 elephants was not massed closely as the animals shuffled past us. Soon after the leading elephant passed us they detected our scent and bolted with snorts and a few restrained screams. Some of the trailing animals crisscrossed very close to us as they reorganized into 2 herds of 11 and 24 individuals and ran out of sight toward the Park.

These observations of rapid reorganization and integrity of family groups, and the behavior of elephants crossing the railroad track near Queen Elizabeth Park (see *Other foods and behavior related to feeding*), suggest the leadership–followership type of animal organization which is basic to the behavior of this species. Allee, *et al.* (1949:411) conclude that, "The contemporary organization of vertebrate groups . . . is based on the application of three general principles: the holding of territory; domination–subordination; and leadership–followership." They also point out (p. 417) that, "Leadership allows greater flexibility of behavior than is usual in territorial or hierarchal organizations."

## SUMMARY

Grass comprised 88 percent of the total food material in the stomachs of 71 African elephants collected during the dry season of 1958–59 near Murchison Falls National Park, Uganda. Although elephants spent considerable time in woodlands, only 10 percent of the food material utilized by 71 elephants consisted of leaves, twigs, and fruit of trees and shrubs. Herbaceous plants were of minor importance as food items for these elephants, comprising about 2 percent of the material in the 71 stomachs.

The importance of grass as a food suggests that maintenance of relatively large areas in grassland in the Murchison Falls National Park region, primarily by fire, may be highly significant to the dense population of elephants which the area currently supports.

During the dry season, elephants (1) concentrated near permanent water supplies where some plants were utilized intensively, and (2) used woodlands primarily for daytime concealment and shade, but not as a principal source of food. With the onset of the rainy season, elephants returned to savanna lands where water was then available and extensive grasslands provided an abundance of their favored foods.

Direct observations of feeding and analysis of stomachs from 19 groups of elephants

indicated that they had specific or primary feeding periods which occurred most frequently during early morning, but varied by groups and time. Minor or secondary quantities of food selected at various times of day and night supplemented their diets.

The stomach contents from 53 elephants ranged from 0.3 to 6 percent of the animal's live weight; the fullest stomachs (for any time of day, sex, and age) weighed from about 5 to 6 percent of the live weight.

My interpretation of data for 19 groups of elephants, and supplemental field observations, lead to three principal conclusions on behavior: (1) the groups of elephants studied represented closely related or family units; (2) the food habits and other behavior of individuals within each group were similar; and (3) the behavior of closely related or family groups suggests the leadership–followership type of animal organization which was basic to the elephant population studied.

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# FOX CALLING AS A HUNTING TECHNIQUE[1]

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Success of fox calling trials carried out the year round under a variety of field conditions in Minnesota has demonstrated the practical value of this technique as a means of sport hunting. Popularization of fox hunting through development of new techniques will do much towards removing the fox from the vermin class and giving it status as a game animal. Factors other than the kind of calling device used are of greatest importance to calling success.

The objectives of this study were to test the effectiveness of fox calling as a means of increasing the utilization of foxes for sport hunting, and to determine the optimum conditions and methods for successful fox calling.

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## REVIEW OF LITERATURE

Game calling as a hunting method is not new. Densmore (1929) described the use of a wooden deer call by Chippewa Indians for daytime hunting. Benson (1948) found the Olts adjustable game call to be highly effective in attracting doe deer (*Odocoileus* spp.). Diem (1954) and Carhart (1959) reported similar success with commercial calls, the former using them to locate fawns by observing the does' reactions during the fawning season.

In western United States the sport of predator calling has been practiced for many years. Alcorn (1946), using a hand-made distress call in combination with a squeak call and howl call, attracted and killed coyotes (*Canis latrans*) in Nevada with amazing success. The Burnham brothers from Texas employed a reed-type mouth call successfully to lure wolves as described by Wiggins (1956) and Dalrymple (1957). Tinsley (1960) reported similar success by the Burnham brothers in calling raccoon (*Procyon lotor*) close enough to be captured in a dip net.

Enticing bobcats (*Lynx rufus*) within easy gun range by use of a reed-type call as well as a lip call when animals were in close range was described by Martin (1959), who emphasized the importance of good vantage, careful observation, and a long waiting period.

Calling foxes within easy gun range has been reported by Linehan (1956) and Cochran (1959) who used reed-type mouth calls and artificial light at night. Loring (1946) and Martin (1958) achieved marked success in calling foxes by the use of the hand-squeak method. Martin stressed the importance of careful selection of calling site and working alone in the field. A crow call was used successfully by Wetmore (1952) to attract gray foxes (*Urocyon cinereoargenteus*); a tolling bell brought in foxes effectively as described by Ellis (1958).

This paper includes an appraisal of the various factors affecting calling and the success achieved with various calls. Little attempt was made to kill animals responding to the calls.

Field work was carried out from February 15, 1958, through March 15, 1959, when the fox population in Minnesota was suggested by bounty records to be near the highest level since 1950. Although calling trials were made throughout Minnesota, roughly 75 percent of the work was confined to the hilly heavily wooded dairyland of the southeast where fox populations were highest. On a sample township in this area, steel trapping gave an index of 5.8 trap nights per fox captured during the period October 6–16, 1959. This index rivals peak success obtained in Wisconsin and in New York by Parker, *et al.* (1957) who used the same technique.

## FIELD METHODS

A portable, battery-operated, high fidelity record player with amplifier and loudspeaker was used effectively to transmit recorded rabbit distress cries in the field. The original plan was to standardize the calls with this unit so that other factors could be measured and compared. Because of operational difficulties, the unit was used only the first 7 months of the study period, and manual or reed-type calls were used on further tests. The results and conditions involved in each trial were recorded on a standard form.

All except one of the eight commercial "predator" calls tested produced high-pitched rabbit-like distress cries. In this

study the distress cry was from 6 to 12 loud, harsh tones in a series which generally lasted from 8 to 12 sec., gradually decreasing in volume and pitch. A quaver, controlled by the throat, near the end of this period added a realistic touch. Each series of squeals was delivered every 30 to 90 sec. "Toning down" the last few squeals or blasts gave them a quality especially attractive to responding foxes.

At each trial, intermittent calling continued at least 15 minutes. If no fox appeared within 10 minutes, a second calling device of different type often was used. During subzero weather, frozen moisture on the vibrating reed of some mouth calls caused malfunction.

Calls tested were not equally audible to the human ear. All except one of the manually operated calls were heard in open areas at distances ranging from 1,000 to 2,000 ft. when there was little or no wind. The call amplified by the hi-fi record player and the sound of the shrill Olts call carried about ½-mile over open level ground, with no wind. Such factors as tree cover, rolling terrain, and falling snow markedly reduced the distance at which any call was heard.

Fox calling trials were made under a wide variety of habitat and weather conditions, largely during daylight hours and in each month of the year. The majority of calling sites were selected arbitrarily in unfamiliar country by recognition of good fox habitat. Once the general site was routinely surveyed from an automobile, the specific calling site was chosen by the operator on foot. Ordinary drab clothing was worn at all seasons.

At each calling trial the prevailing physical conditions were tabulated. Barometric pressure was recorded for only a 9-mo. period beginning June 1958. Wind velocity and distance to the nearest road or human habitation were estimated. Cover density at the calling site was expressed in terms of concealment afforded by vegetation and natural obstructions to a fox approaching within 200 ft. of the observer. For example, heavy cover on all sides of the observer meant that all quadrants offered full concealment. Light or somewhat open cover provided partial concealment; an open quadrant was one entirely devoid of cover in which a fox might find concealment.

## RESULTS AND DISCUSSION

Four hundred and one calling trials were made during the 13-mo. test period; 14.4 percent were successful. Three red foxes (*Vulpes fulva*) were called in for each gray fox. The exact statewide ratio of red to gray foxes is not known, although red foxes predominate over most of the state. Bounty records do not differentiate between the two species.

In most cases foxes were quick to respond to the distress calls (Table 1). Of 73 foxes called in, 74 percent responded within 10 min. One out of every four responded within 3 min.

Since one out of seven trials was successful and an average of 15 min. was spent per trial, approximately 2 hr. were required to call in a fox. This compares favorably with other methods of fox hunting but has the added advantage of not requiring dogs or a large group of hunters.

Included in the successful calls were 1 triple (three red foxes responding at one time at one site) and 13 doubles. At three separate sites, foxes were called in from active dens in April and June.

Three out of every four foxes approached to within 150 ft. of the observer. One out of every two approached to within 50 ft.; and one animal approached to within 10 ft. All foxes except one were called within rifle range—less than 650 ft.

TABLE 1.—TIME INTERVAL REQUIRED FOR FOXES TO RESPOND TO CALLING

| Minutes Before Response | Number of Foxes Responding | Percent |
|---|---|---|
| 0–3 | 18 | 24.6 |
| 4–5 | 21 | 28.8 |
| 6–10 | 15 | 20.5 |
| 11–15 | 8 | 10.9 |
| 16–20 | 4 | 5.5 |
| 21–25 | 1 | 1.4 |
| Over 25 minutes | 1 | 1.4 |
| Undetermined | 5 | 6.9 |

Nineteen percent of the 21 calling trials made from an automobile were successful. This suggests that normal fear of man and his activities may be masked by a car or completely offset by hunger or curiosity. Calling from tree sites was successful in 4 of 18 attempts. The importance of elevation in counteracting human scent was suggested at one site when an unsuspecting red fox approached upwind to within 25 ft. of two observers who were standing only 6 ft. above the ground in the crotch of a large tree.

Calling success did not depend on using any particular calling device. Seven different commercial reed-type mouth calls were tested and all were effective in attracting foxes. Each of four veteran fox callers contacted in the field effectively used a different type of commercial call. Only 10 percent of the calls made with the hi-fi record player were successful. This comparatively low success was believed due to record background noise, the difficulty of maneuvering the machine into position, and the poorer vantage resulting from operating it on the ground.

A rubber squeeze-bulb call producing a sharp resonant squeak showed great promise, particularly for close work. On four different occasions foxes which hesitated at varying distances from the operator after answering a louder reed-type call were attracted to within 50 ft. by the squeeze-bulb call.

Because of the difficulty of separating the numerous and complex factors affecting calling success, the findings of this study did not lend themselves to statistical analysis. It is believed, however, that the results obtained are encouraging and may well serve as a guide to future work in this field.

## TANGIBLE FACTORS AFFECTING CALLING SUCCESS

The optimum daylight period for calling foxes was from 3 hr. before sunset until dark (Table 2). Twenty percent of the calls tried during this period were successful, and 60 percent of all successful calls fell within this period. Small success attended early morning calling and may have been due to reduced fox feeding activity. Although only 12 field trials were made at night, one-third of these attracted foxes.

TABLE 2.—RESPONSE OF FOXES AT VARIOUS HOURS TO CALLING

| Calling Period | Number of Calls | Percent Success |
|---|---|---|
| Dawn to 1 hour after sunrise | 51 | 11.8 |
| 1–3 hours after sunrise | 53 | 3.9 |
| 3 hours after sunrise until noon | 60 | 13.3 |
| Noon to 3 hours before sunset | 23 | 13.0 |
| 1–3 hours before sunset | 54 | 20.4 |
| 1 hour before sunset until dark | 148 | 16.3 |
| After dark with artificial light | 12 | 33.3 |

Calling success varied from 7 percent to 28 percent for each month of the year, which supports the contention that fox calling is a year-round sport. April, May, and August appeared to be the best months for calling but the percentage differences of calling success may not be significant.

Wind velocity (Table 3) proved to be the most important weather factor affecting calling success. Calling success was high-

TABLE 3.—METEOROLOGICAL EFFECTS ON SUCCESS IN CALLING FOXES

| | Number of Calls | Percent Successful |
|---|---|---|
| Wind velocity | | |
| Less than 3 m.p.h. | 193 | 20.2 |
| 3–4 m.p.h. | 98 | 11.2 |
| 5–10 m.p.h. | 85 | 8.2 |
| Over 10 m.p.h. | 25 | 4.0 |
| Barometric pressure | | |
| Falling | 49 | 12.2 |
| Steady | 115 | 21.7 |
| Rising | 30 | 23.3 |
| Temperature | | |
| Below 0°F. | 18 | 16.6 |
| 0°–15°F. | 30 | 16.6 |
| 15°–30°F. | 76 | 15.8 |
| 30°–45°F. | 110 | 12.7 |
| 45°–60°F. | 60 | 16.6 |
| 60°–75°F. | 81 | 11.1 |
| Over 75°F. | 26 | 19.3 |

est with a wind velocity of 3 m.p.h. or less, but decreased progressively as the wind became stronger. On a rising or steady barometer calling success increased; on a falling barometer it decreased. These effects may have been masked, however, by the relation of wind to changes in barometric pressure. Observations on the effects of temperature, cloud cover, light intensity, and ground conditions on calling were inconclusive.

Although many foxes were called up and seen in fairly heavy cover, the advantage to the caller of unrestricted visibility in every direction became more apparent as testing progressed (Table 4). At sites where all quadrants were open, observed calling success, measured by foxes actually sighted, was over twice as high as at sites offering some concealment to an approaching fox. This does not imply that fox response increased but that observability may overshadow the importance of approach cover. The 18 percent calling success achieved at sites nearest to human habitation suggested that this influence did not seriously affect fox response (Table 4). The effect of cover type and topography upon fox response was obscure.

### INTANGIBLE FACTORS AFFECTING CALLING SUCCESS

Careful selection of a calling site is a prime consideration for calling success. High ground commanding a good field of vision is most desirable. A weedy fence row, windfall, brush or weed patch, or a tree clump in an open area are examples of good calling sites. Full concealment for the observer is not necessary if he remains motionless (Fig. 1).

TABLE 4.—EFFECT OF COVER DENSITY AND HUMAN ACTIVITY ON SUCCESS IN FOX CALLING

| Environmental Factor | Number of Calls | Percent Successful |
|---|---|---|
| Cover density | | |
| All quadrants with partial or full concealment | 189 | 14.3 |
| One quadrant open | 59 | 10.2 |
| Two or three quadrants open | 139 | 14.4 |
| All quadrants open | 14 | 35.8 |
| Nearest road or human habitation | | |
| Less than ⅛ mi. | 89 | 18.0 |
| ⅛–¼ mi. | 101 | 9.9 |
| ¼–½ mi. | 181 | 13.8 |
| Over ½ mi. | 30 | 23.3 |

FIG. 1. Winter calling site in fox habitat showing caller in relation to coverts.

The caller's method of approaching the calling site is extremely important to the success of any calling trial. The observer must gain position without detection by foxes present in the vicinity. He must approach the site quietly and cautiously against the wind via the edge of a woods, brushy fence row, or windbreak.

Skill of the operator in manipulating his call is important. The rabbit distress cry must have "feeling" and sound realistic. The novice caller should become familiar with rabbit cries in the wild and should also work with an experienced caller.

The alertness of the caller bears heavily on success. A responding fox may seem to appear suddenly from nowhere. Occasionally the alert operator may hear a fox walking on dry leaves or grass and may even detect its scent. If the observer is not constantly alert, a responding fox may come within 50 ft. without being seen. This happened several times to the writers, as shown by tracks in the snow.

Food preferences and availability of food may exert a strong influence on fox response. On five of six occasions foxes were observed hunting mice within range of the call, yet they would not respond to any of

several different rabbit distress calls. This may indicate a preference for mice. At another trial late in the morning a sleeping red fox was observed at a distance of 660 ft. lying on the sunny side of a hay bale. During 70 min. of testing three commercial calls, this fox responded only to the extent of rising up to peer over the hay bale towards the call. Presumably, this animal was neither hungry nor curious.

## FOX BEHAVIOR

Reactions of foxes to calling under varying conditions are a constant challenge to the ingenuity of the caller. At times, curiosity may account for an unexpected response. Some foxes come directly to the call unhesitatingly, even upwind, and may approach to within 15 ft. Most animals, however, approach downwind to within 100–200 ft. before stopping to reassure themselves that all is well. If a fox's suspicions are aroused after coming in closer, the animal may circle slowly downwind, almost invariably catch the operator's scent, and race for cover. On several occasions, foxes "spooked" immediately on encountering the caller's fresh footprints.

Foxes answering the call cannot always be seen. During a heavy snowstorm in dense woods, a single gray fox answered the call from its den 650 ft. away. A second fox approached the same calling site at the same time but was never seen. Tracks in the fresh snow showed that it had come from its hunting perch on a knoll 1,000 ft. distant but had remained out of sight in heavy cover.

A single type of call brought in both red and gray foxes at the same time and place on two occasions. At another site, under identical conditions, two different foxes responded to two different calls. This suggests that conditioning of individual foxes to natural calls may play a part in response to artificial calls. Some foxes for unknown reasons were repelled by certain calls.

Most of the foxes answering the calls came in walking or trotting, and not always on a straight line. Foxes running to the call were recorded at only eight different sites; four of these responded to reed-type calls and four to the recorded rabbit squeal. At nine calling sites, representing 16 percent of the successful calls, foxes crossed an opening in approaching the caller. The usual approach was via some type of cover, for which the observed success appeared to be lower.

Several calls successfully brought in foxes which had been heard barking in heavy wooded cover immediately preceding the field trial. In three instances, foxes responding to a call barked as they approached.

Measured distances to points from which foxes responded to calling were determined by backtracking in fresh or melting snow, but opportunities to backtrack foxes were limited because of the open winter. Four individuals travelled straight line distances of 650, 1,000, 1,050 and 1,100 ft. respectively. Two of these foxes had been hunting and two were presumably resting, one inside a rock den. Two other individuals had responded to the call from unknown points farther than 600 ft. from the operator.

## SUMMARY

A study to evaluate and develop fox calling as a hunting technique was conducted in Minnesota during the period from February 15, 1958, to March 15, 1959. Calling trials were made under a wide variety of recorded field conditions. Seven commercial calling devices and a hi-fi record player producing rabbit distress cries were tested for their effectiveness in attracting foxes within shotgun range. All calling devices attracted foxes and no single one proved infallible. Foxes were called successfully, at all seasons, in 14.4 percent of the 401 field trials. Conditions most important to success included (1) calling late in the day, (2) calling when wind velocity was less than 3 m.p.h., and (3) skillful approach of the operator to the calling site.

Fox calling is recommended as a useful technique for luring foxes to observers or hunters, and has great potential as a sport.

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# PROPORTION OF RECOVERED WATERFOWL BANDS REPORTED

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Many banded waterfowl taken by hunters are not reported (Bellrose, 1955). In using band recovery data, investigators have had to assume that recovered bands are reported at the same rate from all regions of the country and from all species.

The present investigation was undertaken to measure the proportions of recovered bands that were reported. Comparisons were made to determine whether these proportions differed by region and species and to learn whether band reports from state and federal conservation agency employees affected the over-all proportions of bands taken that were reported.

The procedure was to use the Bureau of Sport Fisheries and Wildlife's annual questionnaire to waterfowl hunters to estimate the number of banded birds that were shot, then to compare this estimate with the number of bands from hunter-killed birds that were reported to the Banding Office. It was possible to separate the band reports to the Banding Office into categories consisting of those bands returned directly by the hunters who killed the birds and those bands reported by other sources (chiefly conservation agencies).

Annually, the Bureau mails a questionnaire to a large sample of waterfowl hunters. This survey is described by Crissey (1959). Basically, the plan is to select U. S. post offices at random and request each person who purchased a waterfowl stamp at one of those post offices to remit his name and address on a special form. Questionnaires are sent to all who returned the form (about half of those buying stamps at these post offices). Questions about banded birds were asked in regard to four hunting seasons: 1954–55 through 1957–58. In each of these years, one question asked for the number of banded waterfowl the hunter had bagged. In the first three years, hunters were asked in a second question to list the band numbers and dates they were taken. The second question was omitted in 1957–58 because we suspected that some hunters who did not know the band numbers might be reluctant to report that they had shot banded birds.

For analysis of the data from the questionnaire, replies were grouped according to state and year. The number of banded birds shot in each state in each year was

then estimated by multiplying the average number of banded birds reported per hunter by the number of Migratory Bird Stamps sold in the state in that year, with a minor correction for philatelic sales. Estimates for larger areas and longer periods of time were made by combining the estimates for the individual states. Estimates made in this manner are properly weighted for the relative number of hunters in each state. The total kill of banded waterfowl in the United States was estimated for the four hunting seasons from 1954–55 through 1957–58. The proportion of bands from birds shot by hunters that was reported by all sources of reports was estimated by comparing the estimated total kill of banded birds with the number of banded birds reported to the Banding Office as taken by hunters.

The reliability of the estimates of numbers of banded waterfowl taken depends on the validity of the following assumptions:

1. It is assumed that the sampling error is not too great. The possible sampling error of the estimate of the total kill of banded waterfowl for the 1956–57 season was estimated by the Institute of Statistics at North Carolina State College to be ±17.6 percent at the 95 percent confidence level. (Report prepared for the Bureau of Sport Fisheries and Wildlife, titled "A Comparison of the Precision of Various Estimators for Estimating Waterfowl Kill from Survey Data," January 20, 1958.) Sampling error estimates for individual administrative flyways ranged from 24.5 to 35.9 percent. We believe the sampling errors of our estimates would be less than those from the flyways, because each state was treated as a unit and data from more than one year usually were combined.

2. It is assumed that hunters respond correctly to the questions about banded waterfowl. The validity of this assumption is not known. Change in the wording of the questionnaire in 1957–58 appeared to affect the estimates; thus this assumption probably is not entirely valid. It seems likely, however, that during the years when the questionnaire was the same each year that a valid index of the total kill of banded birds was obtained.

3. It is assumed that the hunters who did not answer the questionnaire shot proportionately the same number of banded birds as the hunters who did answer. Atwood (1956), in his study of the validity of mail surveys of bagged waterfowl, concluded that the characteristics of non-respondents and respondents were similar. If this finding also applies to hunters taking banded ducks, then this assumption is valid.

4. It is assumed that hunters who shot a banded bird knew they had done so. It is conceivable that some hunters may shoot a banded bird and not notice that it is banded.

Estimates also were made of the kill of banded birds of different species. This was more difficult because the band numbers were not included in about 20 percent of the questionnaires reporting bands; thus there was no way of identifying the species. Furthermore, some of the bands that were reported were bands not issued by the Fish and Wildlife Service. These non-Service bands were reported from all flyways, but most commonly from the Atlantic and Mississippi Flyways, where they made up an estimated 28 and 5 percent, respectively, of the band reports. For purposes of estimation, we assumed that the proportion of non-Service bands among birds reported from a state for which no band numbers were reported was the same as among those for which numbers were provided. We assumed, also, that the species composition among birds taken in a state for which no band numbers were reported was the same as among those for which numbers were reported.

The Banding Office files were examined to determine the source of band reports, i.e., whether they came directly from hunters, whether they had been sent in by state or federal conservation agency employees, or in relatively few instances from other specific sources such as newspaper writers or duck pluckers. Only recoveries from birds shot by hunters were considered; all

recoveries from birds killed any other way were excluded. To obtain these data we examined about 25 percent of all the recovery letters received by the Banding Office between January 1, 1950, and July 1, 1957. Selection was made by taking all recovery letters from every fourth folder in the files of the Banding Office. Each folder contained letters relating to recoveries from a single bander. Reports from hunters' wives, hunting companions and secretaries were regarded as coming from the hunters. When a conservation agency employee reported a band from a bird he himself bagged, the report was recorded as coming from a hunter. Each band recovery was tallied as to reporting source, species, year of recovery, and state where recovery was made.

Table 1 shows the estimated numbers of banded ducks shot in the United States and the estimated proportions reported. Data are grouped according to the percentage of reports coming directly from hunters. The group of states from which the highest proportion of bands was reported had the lowest percentage reported directly by hunters. This suggests that the reporting of bands from hunter-killed ducks by persons other than hunters (usually conservation agency employees) increases the band-reporting rate.

Table 1 shows also that the estimated proportion of bands taken that were reported was greater for the seasons 1954–55 through 1956–57 than for the 1957–58 season. The change in the wording of the questionnaire for the 1957–58 season, when band numbers and dates taken were no longer requested, probably was responsible for the drop in the estimated band-reporting rate. There are two possible explanations for this drop. First, estimates of banded birds shot in the seasons 1954–55 through 1956–57 may have been too low because some hunters may have been reluctant to report banded birds when they did not know the band numbers or dates taken. The other explanation is that estimates for 1957–58 may have been too high because some hunters may not have noticed that the question referred to banded birds, and consequently may have reported as banded some birds that were not banded. This oversight was less likely in the replies from seasons 1954–55 through 1956–57 because the additional request for band number and date made it obvious that the inquiry referred to banded birds. It seems likely that the proportion of bands returned actually was not greatly different in the two periods, and lay somewhere between the 1954–57 and the 1957–58 estimates shown in Table 1.

As the next step in the analysis we estimated the proportion of bands taken that

TABLE 1.—NUMBERS OF BANDED DUCKS SHOT AND THE PROPORTIONS REPORTED (All species combined. States grouped according to percentage of reports that came directly from hunters)

| Area | Percentage of Band Reports Coming Directly from Hunters | | No. of Recovery Reports in Banding Office Sample | Banded Birds That Were Shot | | | |
|---|---|---|---|---|---|---|---|
| | | | | Estimated Numbers | | Proportion Reported (all sources) | |
| | Range | Mean | | 1954–55 through 1956–57 | 1957–58 | 1954–55 through 1956–57 | 1957–58 |
| A[1] | 84–96 | 89.3 | 5,911 | 38,857 | 16,833 | 0.477 | 0.381 |
| B[2] | 67–83 | 73.4 | 6,379 | 35,823 | 19,027 | 0.512 | 0.404 |
| C[3] | 46–66 | 63.3 | 6,321 | 32,210 | 14,478 | 0.617 | 0.465 |
| Entire U. S. | 46–96 | 75.0 | 18,611 | 106,509 | 50,338 | 0.531 | 0.432 |

[1] Includes 21 states: Ala., Ark., Conn., Ga., Ill., Kan., Ky., La., Miss., Nebr., N. H., N. J., N. Y., N. C., N. Dak., Okla., Pa., S. C., Tex., Va., W. Va.

[2] Includes 22 states: Ariz., Colo., Dela., Fla., Idaho, Ind., Iowa, Md., Mass., Mich., Minn., Mo., Mont., N. Mex., Ohio, R. I., S. Dak., Tenn., Vt., Wash., Wisc., Wyo.

[3] Includes 5 states: Calif., Me., Nev., Ore., Utah.

were reported by hunters themselves (thus excluding the influence on the reporting rate caused by bands reported through other sources, chiefly conservation agency employees). Under this condition, the proportion ($p$) of bands taken that was reported was estimated by solving the following equation:

$$p = \frac{ab}{c - da}$$

where

$a$ = total bands from hunter-killed birds reported to the Banding Office from all sources;
$b$ = proportion of these band reports made directly by hunters as judged by Banding Office sample;
$c$ = total number of banded birds shot as estimated from the questionnaire;
$d$ = proportion of band reports from sources other than hunters, chiefly conservation agency employees (or $1 - b$).

For example, for Area A, during the hunting seasons 1954–55 through 1956–57, $a$ was 18,535 (to obtain from Table 1: $38{,}857 \times 0.477$); $b$ was 0.893; $c$ was 38,857; and $d$ was $1.00 - 0.893$ or 0.107. Substituting these values in the above equation, we found the proportion of bands taken and reported by hunters was:

$$p = \frac{18{,}535 \times 0.893}{38{,}857 - (0.107 \times 18{,}355)} = 0.45$$

The estimated proportion for Area B was 0.43 and for Area C was 0.50. These proportions differed less from area to area than those in the last two columns of Table 1, which were based on data from all sources.

The formula used to make these estimates assumes that the proportions of band reports from hunters and conservation agency employees were accurately estimated from the sample from the Banding Office files. This assumption may not be entirely met because a small proportion of the band reports from conservation agency employees may not have been recognized as such. It also is assumed that conservation agency employees report all the bands they receive from hunters. This assumption also is probably almost but not entirely met.

A comparison of band-reporting rates and sources of band reports for the three areas defined in Table 1 illustrates the relationship between the source of band reports and the proportion of bands taken by hunters that are reported. This comparison indicates that as the proportion of reports from persons other than hunters increases, the proportion of all bands taken that are reported also increases. It also shows that after the influence of reports from sources other than hunters has been eliminated, the proportion of bands taken that are reported differed less among areas than did reporting rates based on all sources of band reports. This strongly suggests that much of the differences among regions in the proportion reported of all bands taken by hunters may be credited to differences in the extent to which conservation agencies report bands.

There were enough reports from mallards that analyses similar to those for all species (Table 1) could be made separately for the single species. Results relating to the mallard for the 1954–57 seasons are shown in Table 2. As was expected, the highest proportion of bands was reported from the region where the lowest fraction of reports came directly from hunters; and the lowest proportion of bands was reported from the region where the highest fraction of reports came directly from hunters. Data for mallards were analyzed further by grouping them according to administrative flyways. Results for the seasons 1954–55 through 1957–58 are shown in Table 3. The proportion of bands reported from the Pacific Flyway was 0.61, whereas the proportion from the Mississippi Flyway was only 0.42. The principal reason for this discrepancy probably was that 34 percent of the reports from the Pacific Flyway came from sources other than hunters, chiefly from employees of state and federal conservation agencies,

TABLE 2.—NUMBERS OF BANDED MALLARDS SHOT AND THE PROPORTIONS REPORTED (States grouped according to the percentage of reports that came directly from hunters)

| Area | PERCENTAGE OF BAND REPORTS COMING DIRECTLY FROM HUNTERS | | No. of Recovery Reports in Banding Office Sample | BANDED BIRDS THAT WERE SHOT 1954–55 THROUGH 1956–57 | | |
|---|---|---|---|---|---|---|
| | Range | Mean | | Estimated Number | Number Reported | Proportion Reported (all sources) |
| A[1] | 45–62 | 60.4 | 2,587 | 10,527 | 7,144 | 0.679 |
| B[2] | 67–83 | 77.2 | 3,199 | 20,270 | 9,382 | 0.463 |
| C[3] | 84–100 | 88.9 | 3,373 | 24,074 | 10,874 | 0.452 |
| Entire U. S.[4] | 45–100 | 76.7 | 9,159 | 54,871 | 24,400 | 0.499 |

[1] Includes 7 states: Ariz., Calif., Nev., Ohio, Ore., Utah, Vt.
[2] Includes 17 states: Colo., Dela., Fla., Ga., Idaho, Ind., La., Md., Mich., Minn., Mo., Mont., N. Mex., Pa., Wash., Wisc., Wyo.
[3] Includes 21 states: Ala., Ark., Conn., Ill., Iowa, Kan., Ky., Mass., Miss., Nebr., N. J., N. Y., N. C., N. Dak., Okla., S. C., S. Dak., Tenn., Tex., Va., W. Va.
[4] Includes 45 states as too few data were available for Me., N. H., and R. I.

whereas only 17 percent of the reports from the Mississippi Flyway came from persons other than hunters.

A study made by Bellrose (1955) of mallards banded in Illinois includes certain data that can be compared with ours. In his Table 3, p. 73, he showed that 14.6 percent of the birds that were banded with standard bands were reported, whereas 32.4 percent of those banded with $2-reward bands were reported. If it is assumed that all reward bands taken were reported, then it can be calculated that only about 45 percent of the standard bands taken were reported ($14.6 \div 32.4 = 0.45$). The assumption may not be entirely true, since at least a few people probably failed to report bands even though a reward was offered. The true proportion, therefore, probably was somewhat less than 0.45. Our estimate for the Mississippi Flyway was 0.42, a close agreement.

Banded birds of other species were less numerous than banded mallards. There were enough data, however, to make species estimates for the United States as a whole (Table 4) for the hunting seasons 1954–55 through 1956–57. The estimates for individual species are less reliable than those made earlier for all species combined. This is particularly true for the less numerous species of ducks, where samples are small.

TABLE 3.—NUMBERS OF BANDED MALLARDS SHOT AND THE PROPORTIONS REPORTED FOR HUNTING SEASONS 1954–55 THROUGH 1956–57 (Data grouped according to flyways)

| Flyway | BANDED BIRDS THAT WERE SHOT | | |
|---|---|---|---|
| | Estimated Number | Number Reported | Proportion Reported (all sources) |
| Pacific | 15,129 | 9,197 | 0.608 |
| Central | 12,725 | 6,442 | 0.506 |
| Mississippi | 24,068 | 10,138 | 0.421 |
| Atlantic | 2,957 | 1,623 | 0.549 |

The data indicate that 65 percent of the banded pintails and 64 percent of the banded canvasbacks that were shot were reported to the Banding Office. Proportions for all other species were lower. For some species, the proportion of bands reported may have been at least partially influenced by the number of reports from conservation agency employees. For example, a relatively high proportion of banded pintails was reported and a relatively high percentage of the reports came from conservation agencies, whereas a low proportion of banded black ducks was reported and a low percentage of band reports came from conservation agencies. This seems to be insufficient explanation for the results obtained for all species, however. The relatively high proportions for canvasbacks and redheads may have resulted from the high esteem in which many hunters hold these birds. The proportions of banded birds shot that were reported, after excluding the influence of reports from sources other than hunters, are shown in the last

TABLE 4.—NUMBERS OF BANDED WATERFOWL SHOT AND THE PROPORTIONS REPORTED FOR HUNTING SEASONS 1954–55 THROUGH 1956–57 (individual species)

| Species | BANDS REPORTED | | No. of Recovery Reports in Banding Office Sample | BANDED BIRDS THAT WERE SHOT | | |
|---|---|---|---|---|---|---|
| | Number Reported | Reported by Conservation Agency Employees (percent) | | Estimated Number | Proportion Reported | |
| | | | | | All Sources | Hunters Directly |
| Mallard | 27,400 | 24 | 9,159 | 54,871 | 0.499 | 0.432 |
| Pintail | 12,323 | 29 | 2,935 | 18,935 | 0.651 | 0.569 |
| Black duck | 5,463 | 14 | 1,451 | 11,143 | 0.490 | 0.451 |
| Redhead | 2,130 | 18 | 613 | 3,929 | 0.542 | 0.492 |
| Bw. teal | 1,607 | 20 | 531 | 3,636 | 0.442 | 0.388 |
| Scaup[1] | 1,052[2] | 20 | 309 | 2,367[2] | 0.444 | 0.392 |
| Canvasback | 969 | 13 | 320 | 1,522 | 0.637 | 0.603 |
| Wood duck | 918 | 21 | 316 | 1,872 | 0.490 | 0.432 |
| Gw. teal | 514[2] | 38 | 175 | 1,064[2] | 0.483 | 0.368 |

[1] Lesser and greater scaup combined.

[2] Omits California where the kill estimate obviously was in error.

column of Table 4. For the species of ducks for which more than 2,000 bands were estimated to have been taken, the data suggest that the proportions reported of bands taken differed less among species when based solely on hunter reports than when based on reports from all sources.

## SUMMARY

Data from the annual mail survey of waterfowl hunters in the United States were used to estimate the total numbers of banded waterfowl that were shot. These estimates were compared with Banding Office records to estimate the proportion of recovered bands that was reported. On the average, about two banded birds were recovered for each one reported. The proportion reported was higher for some areas and for some species than for others. The proportion reported was higher when more of the reports came through employees of conservation agencies.

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# INCIDENCE OF LEAD IN LIVERS OF ILLINOIS RACCOONS

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Attempts to determine the cause of severe losses among raccoons in several localities in Illinois led to the discovery of a high incidence of lead in the livers of the animals examined. This frequent occurrence, and the occasional high level of lead in individual livers, suggested that lead might be a contributing or primary cause of death. Lead poisoning, however, is an extremely complex problem, even in man where much work has been done; and a critical study of the relationship of lead to mortality in raccoons proved to be beyond reach of the authors. Nevertheless, in view of the interest in lead poisoning and its seriousness in several domestic animals as well as in waterfowl and man, a report on the incidence of lead in raccoons and its possible significance is believed desirable.

Lead poisoning has been recognized as a cause of mortality in waterfowl for over 60 years (Bellrose, 1959). More recently it has been found to constitute a human health problem (Cantarow and Trumper, 1944). It has also been reported in domestic mammals (Allcroft, 1950).

Cantarow and Trumper (1944:8) believe that "Although there is no evidence that lead is an essential constituent of the body, many studies with improved technical methods indicate . . . that the average individual in a modern community continually ingests or inhales small amounts of lead. Consequently, although the term 'normal' may not be strictly applicable to lead as a constitutent of the body tissues, it is important to recognize . . . that certain amounts of this element may be present in the blood and tissues of normal individuals who have not been exposed to unusual quantities . . . ." They also point out that since 1926 improved analytic methods have made it possible for many workers to find lead in tissues, especially the skeleton, of practically all normal subjects investigated.

Kehoe, *et al.* (1933b) reported the mean daily intake of lead for various groups of normal Americans varied from 0.25 to 0.38 mg., mostly in food and drink. According to Cantarow and Trumper (1944), 0.08 to 0.10 mg. are taken in daily by inhalation.

Lead probably occurs in the tissues of living organisms to a greater extent than is generally known. Kehoe and Thamann (1929) indicate that the incidence of lead in the carcasses of experimental animals suggests that tissues of meat-producing animals contain significant amounts. Kehoe, *et al.* (1933a) report minute quantities in crawfish, freshwater fish, ground corn, and a lizard (*Ajolotes*). Chapman and Linden (1926) state that lead has been found in a variety of marine fish, shellfish, and crustaceans. New and relatively simple techniques for microanalysis of lead in tissues (Hammond, *et al.*, 1956; Karlog and Møller, 1958) may further encourage studies of lead in a variety of species.

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## Methods

Conservation officers of the Illinois Department of Conservation were requested to report unusually severe mortality among raccoons and to submit fresh specimens for

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autopsy when possible. Similar cooperation was solicited from raccoon hunters.

Starting in 1956, when sick and dead raccoons began to come in, routine autopsies, which did not include lead analyses, were made at irregular intervals. Livers were routinely checked for lead content when the microanalytic technique of Hammond, *et al.* (1956) became available.

When relatively high concentrations of lead were found in the livers of many raccoons, livers were collected at random from 101 raccoons at fur-buying stations to determine the incidence of lead. Thirty-two of these livers came from raccoons killed in January of 1959 and 69 in December 1958. Ninety of these livers were obtained from the Perardi Brothers Fur and Wool Company, Farmington, Fulton County, Illinois, and they were killed within a radius of about 100 mi. around Farmington. The remaining 11 livers were obtained from Mr. Jerry Brazelton, Monticello, Piatt County, Illinois, and probably came from an area within a 25-mi. radius of Monticello.

Data on sex, age, breeding history, weight, body length, and body condition were obtained for most of the raccoons from which livers were obtained. A condition factor ($K$) was calculated using the formula $K = W/L$ in which $W$ = weight in grams and $L$ = body length in millimeters.

Adrenal glands were removed, hardened in 10 percent formalin, and later cleaned and after drying for 1 minute on a paper towel, were weighed to the nearest tenth of a milligram on a microtorsion balance. As a measure of stress, weights of paired adrenal glands were calculated as milligrams per millimeter of body length. In research on the effects of stress in Norway rats (*Rattus norvegicus*), Christian and Davis (1955) found that the logarithm of the body weight in milligrams plotted against body length in centimeters gave a better linear relationship than did other standard measures.

One captive female raccoon was forcibly fed small amounts of white lead in 3-, 5-, 10-, and 20-g. doses on an irregular schedule from June 12, 1958, through October 13, 1958, for a total of 121 g. of white lead for the period. The white lead was weighed, rolled in a small ball of moist bread, and placed in the back of the raccoon's mouth. Usually, the bread was swallowed immediately, but, if refused, a small amount of water was squirted into the animal's mouth, causing the pellet to be swallowed.

Because it was thought that gasoline might in some way have contributed the lead in the livers, approximately 2 tablespoonfuls of leaded gasoline were poured into the drinking water of two captive females each day from September 16, 1958, to October 16, 1958, and from March 1, 1959, to March 15, 1959. On March 19 and June 22 liver biopsies were taken from one of the females. Both animals were killed on July 23, 1959, a little more than 44 weeks after the leaded gasoline was first added to the drinking water and more than 18 weeks after it was discontinued. Unfortunately, liver biopsies were not taken prior to feeding lead to these raccoons; however, data from several captive raccoons which were not given lead, including both adults and young only a few days old, are available for comparison.

Unless otherwise noted, lead content refers to the liver and is given as micrograms (1 $\mu$g. = 0.000,001 g.) of lead per gram of liver. Animals less than 1 year of age are classified as juveniles; those more than 1 year of age as adults.

The $t$ test was used to test for significance at the 5 percent level of differences in levels of lead between the means of the various sex and age groups and seasons.

## RESULTS

Fig. 1 indicates the parts of the State from which 149 livers from wild raccoons came for analysis and the results of the analysis. The livers which were positive for lead showed wide geographic distribution.

The mean concentration of lead in the livers of the 101 wild raccoons killed by hunters and trappers during December 1958 and January 1959 was $6.8 \pm 1.8$ $\mu$g.

FIG. 1. Counties in which 149 wild raccoons were killed or found dead from August 8, 1956 through November 14, 1959.

*These raccoons were collected at fur-buying establishments and probably came from within the corresponding circles on the map.

(Table 1). Only 1 of the 101 raccoons was negative for lead while 23 animals had 10 μg. or more per gram of liver.

Data in Table 2 indicate no significant differences at the 5 percent level, according to the *t* test, between the seasonal levels of lead present except that there was a significant difference between the July–September period and the October–December period. The number of animals available from April through September is small; however, 12 animals autopsied from July–September had only $3.6 \pm 0.9$ μg. of lead compared to an average of $6.3 \pm 0.5$ for 137 animals collected during the other 9 months of the year, and this difference was significant at the 5 percent level.

There were no statistically significant differences in the content of lead in livers of wild raccoons according to age and sex (Table 3). Even so, young females, the majority of which were killed by hunters in December and January, had slightly higher average levels than older females even though the former had less time for exposure to lead. Since most Illinois raccoons are born during April, most of the

TABLE 1.—LEAD IN THE LIVERS OF WILD RACCOONS KILLED BY HUNTERS AND TRAPPERS IN ILLINOIS

| Micrograms of Lead Per Gram of Liver | Number of Animals |
|---|---|
| 0 | 1 |
| 1 | 3 |
| 2 | 11 |
| 3 | 0 |
| 4 | 37 |
| 5 | 0 |
| 6 | 14 |
| 7 | 5 |
| 8 | 7 |
| 9 | 0 |
| 10 | 13 |
| 11 | 0 |
| 12 | 0 |
| 13 | 1 |
| 14 | 0 |
| 15 | 0 |
| 16 | 6 |
| 32 | 3 |
| Mean and S.E. | $6.8 \pm 1.8$ |
| Total | 101 |

TABLE 2.—SEASONAL LEVELS OF LEAD IN LIVERS OF WILD ILLINOIS RACCOONS[1]

| SEASON | NUMBER OF ANIMALS | AVERAGE LEAD CONCENTRATION (Micrograms Per Gram of Liver) | S.E. |
|---|---|---|---|
| Jan.–March | 52 | 5.8 | 0.8 |
| Apr.–June | 9 | 6.2 | 1.1 |
| July–Sept. | 12 | 3.6 | 0.9 |
| Oct.–Dec. | 76 | 6.6 | 0.6 |
| Totals | 149 | 6.1 | 0.4 |

[1] Most were killed by hunters and trappers but some were found sick or dead.

TABLE 3.—LEAD IN LIVERS OF WILD RACCOONS ACCORDING TO SEX AND AGE OR BREEDING HISTORY

| Sex and Age or Breeding History | Number | Micrograms of Lead Per Gram of Liver | | |
|---|---|---|---|---|
| | | Average | Standard Error | Range |
| Adult males | 36 | 6.3 | 0.6 | 0–16 |
| Juvenile males | 35 | 6.3 | 0.9 | 0–32 |
| Parous females | 28 | 6.0 | 0.8 | 0–24 |
| Nulliparous females | 40 | 6.9 | 1.1 | 0–32 |

juvenile raccoons examined for lead were approximately 8–9 months of age.

We attempted to determine whether the amount of lead in the liver was related to the condition factor or the weight of adrenal glands by classifying the animals in two ways: one class of seven groups showing the concentration of lead per gram of liver at intervals of 5 μg. from 0 through 34 μg.; and a second class of two groups showing the concentration from 0 through 9 μg. and from 10 through 34 μg. (Table 4). No significant differences in condition factors were shown by the *t* test for either grouping. Significant differences were evident in the weights of paired adrenal glands between three groups of the seven classes in the first group. Paired adrenals in animals having 0–4 μg. of lead were significantly heavier than animals having 15–19 μg. Likewise, raccoons with 5–9 μg. of lead had adrenals which weighed significantly more than those of raccoons with both 10–14 and 15–19 μg. of lead. The average weight of the paired adrenals from animals having less than 10 μg. of lead per gram of liver was significantly more than from those having 10 or more μg.

Five raccoons found dead, presumably from disease, and 11 obviously sick raccoons, which were either killed immediately or which died after 1–5 days in captivity, had an average of $6.4 \pm 1.3$ μg. of lead and a range of 0–24 μg. (Table 5). These levels were not significantly different from those found in the 101 apparently healthy wild raccoons. However, the average $K$ factor ($5.8 \pm 0.5$) of the apparently diseased raccoons was significantly lower than the average $K$ ($9.0 \pm 0.2$) of the animals killed by hunters and trappers. The average adrenal weights, $1.56 \pm 0.18$ mg. per mm. of body length, in nine of the apparently diseased animals were not significantly higher than the average of $1.31 \pm 0.13$ mg. per mm. of body length found in the animals killed by hunters and trappers.

The captive female force-fed 121 g. of white lead gained weight during the period of feeding. When killed on October 21, it was in good physical condition and showed no gross symptoms of lead poisoning. It had 24 μg. of lead per gram of liver.

One of the two females given leaded gasoline in drinking water had 12 μg. of lead per gram of liver on March 19 and 10 μg. on June 22. The lead content of the liver of each female when killed on July 23, 1959, was 10 μg. per gram. Both were

TABLE 4.—CONDITION FACTORS AND AVERAGE ADRENAL WEIGHTS OF RACCOONS KILLED BY HUNTERS AND TRAPPERS AS RELATED TO LEVELS OF LEAD IN THE LIVER

| Micrograms of Lead Per Gram of Liver | Number of Individuals | Average Condition Factor | Standard Error | Average Weight of Paired Adrenals | |
|---|---|---|---|---|---|
| | | | | Mg. per mm. Body Length | Standard Error |
| 0–4 | 50 | 8.9 | 0.5 | 1.31 | 0.06 |
| 5–9 | 26 | 9.2 | 0.4 | 1.45 | 0.08 |
| 10–14 | 13 | 8.4 | 0.4 | 1.19 | 0.07 |
| 15–19 | 6 | 9.4 | 0.5 | 1.06 | 0.08 |
| 20–24 | 0 | — | — | — | — |
| 25–29 | 0 | — | — | — | — |
| 30–34 | 3 | 9.2 | 0.4 | 1.15 | 0.17 |
| 0–9 | 76 | 9.0 | 0.2 | 1.36 | 0.05 |
| 10–34 | 22 | 8.8 | 0.3 | 1.15 | 0.05 |
| All raccoons | 98 | 9.0 | 0.2 | 1.31 | 0.13 |

TABLE 5.—LEAD CONTENT IN LIVERS OF RACCOONS FOUND SICK OR DEAD, 1958–59

| Sex | Micrograms of Lead Per Gram of Liver | Condition Factor | Average Weight of Paired Adrenals (Mg. per mm. of body length) | Remarks |
|---|---|---|---|---|
| Juveniles | | | | |
| F[1] | 4 | 3.9 | — | Found dead |
| F | 4 | 3.6 | 2.22 | Died after 5 days |
| F[2] | 6 | 7.6 | — | Died after 1 day |
| F | 10 | 4.7 | 1.76 | Found dead |
| F | 10 | 6.4 | 1.30 | Died after 2 days |
| M | 4 | 5.9 | 1.15 | Found dead |
| M | 5 | 2.0 | 0.73 | Died after 4 days |
| M[1] | 6 | 5.5 | — | Died after 4 days |
| Adults | | | | |
| F | 4 | 4.6 | 1.62 | Died after a few days |
| F[1] | 4 | 6.6 | 2.44 | Killed after a few days |
| F | 4 | 9.7 | — | Killed by a farmer |
| F | 6 | 4.8 | — | Died after 5 days |
| F | 24 | 5.0 | 1.16 | Found dead |
| M | 0 | 9.2 | — | Died after 4 days |
| M | 4 | 7.0 | 1.70 | Found dead |
| M[1] | 8 | 7.2 | — | Died after 1 day |
| Average | 6.4 | 5.8 | 1.56 | |
| Standard error | 1.3 | 0.5 | 0.18 | |

[1] Also had pneumonia.
[2] Had been mauled by dogs.

fat and appeared to be in good health at the time of death.

An adult female killed on May 10, 1959, after 20 days in captivity, had 9 μg. of lead per gram of liver. This female's litter of three was about 39 days old at the time of her death. One, approximately 40 days old at death, had 5 μg. of lead; another, approximately 49 days old at death, had 6 μg. of lead; and the third, approximately 195 days old at death, was negative for lead.

Of a litter of six born in captivity on April 18, 1959, one which died on May 29, 3 days after removal from the female, had 9 μg. of lead. One which died on June 22, nearly 1 month after removal from the female, had 8 μg. of lead. Three other raccoons from this litter, which died at 154 to 172 days of age, were negative for lead.

Of five adult raccoons which were in captivity for 5 months or longer prior to death, all were positive for lead, ranging from 2 to 20 μg. Four of these were in captivity for a year or longer and one for as long as 3 years. Of five other captives which were less than 1 year of age, four were in captivity for 5 months or longer prior to lead determination. Two of these were negative for lead, one had 1 μg., and one had 6 μg. The fifth animal was in captivity only 15 days when killed; it had 6 μg. of lead.

## DISCUSSION

While sources of lead available to raccoons were not investigated, there are many possibilities. Many tons of lead paint are used annually, much of which becomes weathered into dust; a wide variety of packaging materials contain lead; lead insecticides and numerous other materials used in growing, packaging, and preparing foods may contain appreciable amounts (Monier-Williams, 1938). It is present on the earth's surface and in the dust of city streets (Selby Smelter Commission, 1915). Finely divided lead from the exhaust of automobiles adds to the top layers of the earth (Kehoe, *et al.*, 1933b), and nearly all coal dust and most soils contain traces of lead (Monier-Williams, 1938). Clarke and Steiger (1914) found lead in Mississippi

silt and in igneous rocks. Kehoe, *et al.* (1933a) show that it was a natural constituent of soil and vegetation as well as animal and human tissues in a commercially undeveloped region of Mexico.

Cantarow and Trumper (1944) state that in humans any lead value above 0.080 mg. per 100 cc. of blood should be regarded as abnormal and that probably the great majority of normal humans without unusual exposure to lead will have below 0.06 mg. of lead per 100 cc. of blood. From preschool age until very old age, lead is maintained at an average concentration of about 0.2 mg. per 100 g. (= 2 μg. per gram) in the liver (Gant, 1939).

Cantarow and Trumper (1944) point out that the quantity of lead producing symptoms of lead intoxication varies widely and depends upon many factors such as age, sex, length of exposure, stress, disease, and path of absorption. Gant (1939) reports that a given amount of inhaled lead is 10–100 times more toxic than is an equivalent amount of ingested lead. There is also a marked difference in susceptibility among species (Cantarow and Trumper, 1944). Jones and Smith (1949) report that four young calves which were given from 2–5 g. of white lead per kilogram of body weight died from 4 to 9 days later. Dogs and cattle are the most susceptible, cats and rabbits only moderately so, sheep and goats slightly susceptible, and rats, mice, and birds most resistant. Judging from our data, raccoons appear to be relatively resistant.

The 12 raccoons autopsied for lead from July–September had significantly lower levels of lead than those from other months (Table 2). Cantarow and Trumper (1944) report that the liver plays three important roles in regard to lead: it removes lead from the blood after absorption from the intestine; it stores large quantities for short periods; and it excretes lead. In addition to the quantity of lead entering the body, the lead content of the liver depends on method of entrance and the duration of exposure as well as the length of time since the last exposure. Generally the largest amounts are found in the liver following gastrointestinal absorption. Kehoe, *et al.* (1933b) report that a state of equilibrium is reached where lead intake and output are balanced over long periods of time, thereby preventing its accumulation in tissues.

No significant differences were found in the lead content of wild raccoon livers according to sex and age (Table 3). Cantarow and Trumper (1944) report that sex and age may influence the amount of lead required to produce symptoms of lead intoxication, and Gant (1939) believes that a constant level may be maintained in humans from preschool age to very old age. Although some investigators believe that there is an increase with age, according to Kehoe, *et al.* (1933b) normal persons whose lead metabolism was followed for prolonged periods showed no evidence of lead accumulation.

Levels of lead found in raccoons during this study apparently caused no visible symptoms, at least in the absence of some other stress factors. Even though some levels were as high as 32 μg. and 23 of the 101 "healthy" animals killed by hunters and trappers had 10 μg. or more, there were no significant differences in the condition factors of raccoons classified by level of lead (Table 4). As previously reported, symptoms of lead poisoning vary widely under the influence of many factors, including species differences.

Curiously, there is a highly significant difference between the adrenal weights in relation to body lengths in raccoons with less than 10 μg. of lead ($1.36 \pm 0.05$ mg. per mm.) and those with more than 10 μg. ($1.15 \pm 0.05$ mg. per mm.). The opposite effect would be expected if the lead were causing stress in this species. Sollman (1922) found that small quantities of lead seemed to have a greater effect on retardation of growth than larger amounts. Retardation of growth and many other effects of lead could be caused by a reduction in pituitary activity. Recently Christian (1959) has shown the lack of correlation between adrenal weight and injury in grouped male white mice. He attributes this to the fact

that the injuries were slight. Probably the levels of lead found here do not place undue stress on the raccoon.

Of 16 sick or dead raccoons examined for lead, 15 were positive for lead with from 4–24 μg. (Table 5). Their average of 6.4 ± 1.3 μg. was not significantly different from the 6.8 ± 1.8 μg. found in 101 "healthy" raccoons killed by hunters and trappers. The 16 sick and dead raccoons were obviously in much poorer physical condition than the "healthy" animals. This is reflected by their average condition factor of 5.8 ± 1.56 which was significantly lower than the average of 9.0 ± 0.2 for the raccoons killed by hunters and trappers. Although the mean adrenal weight and standard error in milligrams per millimeter of body length of 9 of the 16 raccoons was 1.56 ± 0.18 mg. as compared to 1.31 ± 0.13 mg. in the animals killed by hunters and trappers, the differences were not statistically significant.

Of the previously mentioned 16 sick or dead raccoons, 4 had severe cases of pneumonia. It is not believed that the pneumonia necessarily was the cause of illness or death because several apparently healthy raccoons killed by hunters had equally severe cases of pneumonia. The latter animals were not checked for lead. Pneumonia itself did not cause visible symptoms of illness and neither did levels of lead up to 32 μg. in the liver. Of 10 sick raccoons held in captivity until each died or was killed (1–5 days), all showed signs of apparently typical lead intoxication as described by Cantarow and Trumper (1944). According to Shufflebotham (1915), acute symptoms in man may follow injury, influenza, administration of drugs, and increased metabolism such as muscular exercise associated with military training. Shie (1921) states that when an attack occurs suddenly after an individual has been exposed for years, the attacks are due to a sudden change in metabolism and the individual's excretion can no longer keep pace with absorption. Thus, a combination of lead and pneumonia may be a factor in the death of some raccoons; however, 11 of the 16 sick or dead raccoons did not show other visible signs of disease or injury, and one adult male exhibited signs which appeared to be typical of those of lead poisoning, and yet was negative for lead. Five apparently healthy, wild raccoons which were killed had from 4 up to 10 μg. of lead and severe pneumonia at the same time.

The captive female which was given white lead at irregular periods for 4 months, the two captive females which had leaded gasoline added to their drinking water for a period of time, and the five adult raccoons which were in captivity for 5 months or longer, demonstrate that over a period of time the levels of lead which were found in raccoon livers caused no gross symptoms of lead intoxication in these animals. However, Kehoe, *et al.* (1933c) failed to find any correlation between the concentration of lead in the feces, urine, and tissues and the occurrence of signs of lead poisoning. They also point out that lead absorption is not the same as lead intoxication.

Evidence from two litters appears to indicate that lead is passed to young raccoons from their mothers, either via the placenta, via the milk, or both. Four raccoons which died at 65 days of age or less had from 5–9 micrograms of lead. Calvery (1938) proved that there is transfer of lead from the mother to young via the placenta and milk. Karlog and Møller (1958) reported on three cases of acute lethal lead poisoning in humans. In the liver of a fetus from one patient were 21 μg. of lead per gram of liver, 30 percent more than in the liver of the mother.

Based on the evidence from four siblings of the above young raccoons, it appears that lead may disappear from livers of young raccoons if they are maintained for a sufficient length of time on a diet free or nearly free of lead. The four which died from 154 to 195 days of age were all negative for lead. Calvery (1938) reports that storage of lead in bones of young animals is much more rapid than it is in more mature animals. As was discussed above, even after 27–36 months, two adults had 5 and 14 μg. of lead, respectively. Samples of the

food and water given the raccoons were tested for lead on March 19, 1960. The water was negative for lead and, while the food gave a positive reaction, its level was lower than 1 μg. per gram.

Even though obvious effects of lead were not conclusively detected in this study, its potential importance is great. Cantarow and Trumper (1944) report that lead has long been known to be an active abortifacient; and it is generally agreed that if pregnancy does occur it often ends in miscarriage, intrauterine death of fetus, premature birth, and, if living young are born, they are usually smaller, weaker, slower in development, and have a higher infant mortality than normal young. These conclusions are based on observations made on dogs, cats, rabbits, man, and guinea pigs. It is also important for workers investigating levels of lead in wild animals to realize that a low "background level" of lead may be present.

## SUMMARY

Concentrations of lead ranging from 1 to 32 μg. per gram were found in livers of 100 wild raccoons killed in Illinois by hunters and trappers during November and December 1958, and January 1959. Only one liver was negative. Even though possible sources of lead for wild raccoons were not investigated, it is suggested that minute quantities of lead occur routinely in the raccoon's environment. Livers collected from raccoons during July–September had significantly less lead than those collected during October–December. There were no significant differences in condition factors of raccoons as related to concentration of lead in their livers. Adrenal weights of animals with lower levels of lead were significantly heavier than those from raccoons with higher levels of lead. In the absence of other obvious stresses such as injury and disease, levels of lead up to 32 μg. per gram of liver caused no obvious symptoms of lead intoxication in the raccoon. Raccoons appear to be resistant to high levels of lead, but in spite of widely varying responses, lead intoxication, along with other factors, may be a cause of mortality in wild raccoons.

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# AN ANALYSIS OF SIXTY-FIVE YEARS OF FISHING IN A TROUT POND UNIT

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This paper reviews the history and analyzes the present fishery in a trout pond unit owned by the Glen Major Angling Club.

The Club was organized on January 12, 1895, and in that year purchased the 35-a. site of an old mill at the headwaters of Duffin Creek. The fishing unit consisted of three ponds located in series on the creek, the lower two ponds receiving additional cold water from springs and tributaries. The purchase in 1897 of upstream and other adjacent property gave control of the headwaters to the Club. The three original ponds, with occasional renovations, have continued to provide angling for a period of 65 years.

Logbooks and minutes, which have been kept since the inception of the Club, provide excellent data on fish plantings and harvests of trout, and record various management procedures instituted from time to time. Membership is restricted presently to 24 individuals.

The speckled trout (*Salvelinus fontinalis*) is native to the watershed and has provided the fishery exclusively except for a brief experimentation with rainbow trout (*Salmo gairdneri*) stocked in the lowest pond between 1936 and 1939. The first stocking by the Club was made in the lowest pond on May 7, 1895. Trout were first harvested from this pond in 1896 and the catch supplemented by the results of angling in the creek.

The authors wish to acknowledge gratefully the cooperation of A. M. Wilson, President, and members of the Glen Major Angling Club in making available their extensive records and by participating in the biological study of the ponds between 1952 and 1959. Thanks is given to O. E. Devitt, Ontario Department of Lands and Forests, for assistance in the aging of trout used in the growth analysis.

## DESCRIPTION OF POND UNIT

The ponds are located in a wooded valley among moraine hills at the headwaters of Duffin Creek which flows into Lake Ontario some 15 mi. to the south. Geographically, the location is latitude 44°1′ N and longitude 79°3′ W, in the township of Uxbridge, County of Ontario.

The unit consists of three ponds, referred to in this paper as Pond A, Pond B, and Pond C, formed by long earthen dams and arranged in a series as shown in Fig. 1. These are the original ponds taken over by the Club in 1895 but because of ecological aging it has been necessary to deepen the basins and repair the dams from time to time. The present total surface area of the ponds is 5.1 a., which is less than that reported by Ricker (1932) in 1928. The shape of the ponds also differs significantly, as Ricker showed on his map a fourth "nursery pond" of 0.25 a. which is no longer functional.

[1] On loan from the Ontario Department of Lands and Forests.

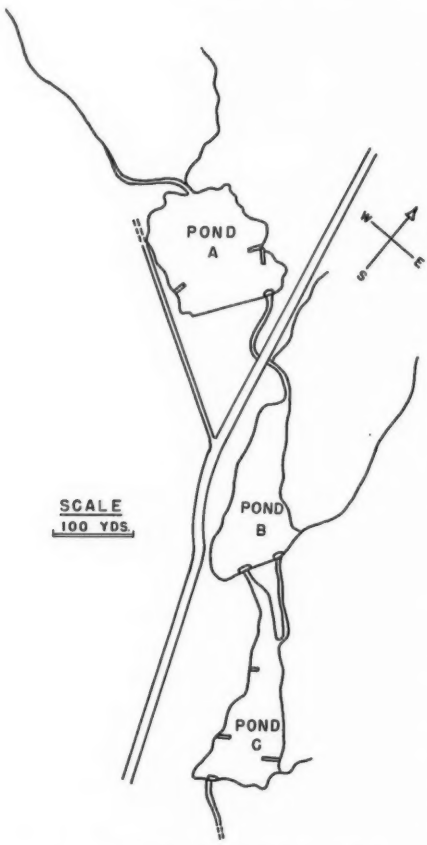


FIG. 1. The Glen Major Fish Pond Unit.

The water supply comes from numerous springs originating largely on the property. The main creek passes through each of the ponds and, on account of inflowing springs and small tributaries, increases gradually in volume from 3.8 to 10.5 cu. ft. per sec. The maximum summer temperature of the main creek increases from an inflow of 12.3°C to an outflow of 17.3°C as it passes through the pond unit. The spring water has a relatively high hydrogen-ion value (*p*H 7.4–7.6) which becomes less as it passes through the ponds, reaching 8.1–8.2 at the outflow. A comparison of these water characteristics with those recorded in 1928 by Ricker (1932) shows no appreciable change during the 30-yr. interval. These data are summarized in Table 1.

Pond A, the largest of the three ponds, has an area of 1.9 a. and a depth of 6 ft. at the lower end. Recent excavation of the silt at the upper end has increased the depth there to about 8 ft. The pond is fed by one creek, which during the summer of 1958 provided a minimum inflow of 3.8 cu. ft. per sec. with a maximum temperature of 12.5°C. Pond temperatures remained low, reaching a maximum of 12.8°C near the surface in September. The deeper regions of the pond are covered with dense mats of *Chara*. The shallow margins are sparsely covered with *Equisetum fluviatile* and *Elodea canadense*. The shore is tree-lined except for a marshy area adjacent to the inflowing creek.

Pond B has an area of 1.6 a. and a maximum depth of 9 ft. at the lower end. The upper end has become shallow because of heavy siltation except in the eastern portion where recent dredging has increased the depth. Water is supplied by the outflow from Pond A at a rate of 5.1 cu. ft. per sec. and from a second creek with a flow of 2.1 cu. ft. per sec. and a maximum observed summer temperature of 8.3°C. Summer pond temperatures in 1958 reached a maximum of 12.9°C near the surface in September. *Chara* is present over most of the pond except in the stream channel which is kept open by the current. There are growths of *Elodea* and *Spirogyra* in the shallow areas. The margin is more marshy than that of Pond A although well wooded onshore.

TABLE 1.—A COMPARISON OF STREAM CHARACTERISTICS OBSERVED IN 1928 (RICKER, 1932) AND 1958

| Location | Minimum Flow (cu. ft./sec.) | | Maximum Temp. (°C) | | pH | |
|---|---|---|---|---|---|---|
| | 1928 | 1958 | 1928 | 1958 | 1928 | 1958 |
| Main creek above Pond A | 3.6 | 3.8 | 12.8 | 12.4 | 7.8 | 7.6 |
| Main creek below Pond C | 10.0 | 10.5 | 16.1 | 17.3 | 8.1 | 8.2 |

TABLE 2.—TEMPERATURE, DISSOLVED OXYGEN, AND CARBON DIOXIDE CHARACTERISTICS OF THE GLEN MAJOR PONDS, 1958

| Pond | Area | Max. Depth (ft.) | Date | Maximum Temperature | | | | Minimum Dissolved Oxygen (p.p.m.) | | Maximum $CO_2$ (p.p.m.) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Surface (at 3 ft.) | | Bottom | | Bottom | Surface (at 3 ft.) | Bottom | Surface |
| | | | | °C | °F | °C | °F | | | | |
| A | 1.9 | 8.0 | June | 10.1 | 50 | 10.2 | 50 | 13.2 | 13.0 | – | – |
| | | | July | 12.4 | 54 | 10.7 | 51 | 9.6 | 10.4 | 9.0 | 7.0 |
| | | | Aug. | 11.6 | 53 | 11.7 | 53 | 7.6 | 9.0 | 9.0 | 8.0 |
| | | | Sept. | 12.8 | 55 | 12.3 | 54 | 9.4 | 9.5 | 12.0 | 12.0 |
| B | 1.6 | 9.0 | June | 11.8 | 53 | 10.1 | 50 | 11.6 | 11.2 | – | – |
| | | | July | 11.7 | 53 | 10.7 | 51 | 9.6 | 8.1 | 10.0 | 6.5 |
| | | | Aug. | 12.3 | 54 | 10.6 | 51 | 10.2 | 10.2 | 14.0 | 11.0 |
| | | | Sept. | 12.9 | 55 | 11.3 | 52 | 9.2 | 9.2 | 8.0 | 8.0 |
| C | 1.6 | 8.5 | June | 16.1 | 61 | 13.5 | 56 | 11.4 | 11.2 | – | – |
| | | | July | 15.8 | 60 | 13.6 | 56 | 9.2 | 9.3 | 14.0 | 6.0 |
| | | | Aug. | 17.3 | 63 | 14.5 | 58 | 10.8 | 9.6 | 17.0 | 12.0 |
| | | | Sept. | 12.9 | 55 | 12.8 | 56 | 9.8 | 9.4 | 7.0 | 9.4 |

Pond C resembles Pond B in many respects, having an area of 1.6 a. and a maximum depth of 8.5 ft. The most striking difference is the increased flow of water through the pond which has scoured out channels in the dense beds of *Chara* and *Elodea*, the latter predominating in the lower end. Water enters the pond from the outflow of Pond B at a rate of 8.4 cu. ft. per sec., from a small cold creek at 0.9 cu. ft. per sec., and from springs within the pond. The outflow approximates 10.5 cu. ft. per sec. Pond temperatures near the surface (at a depth of 3 ft.) in 1958 reached a maximum of 17.3°C during August.

A summary of maximum water temperatures, dissolved oxygen, and carbon dioxide observed in each of the ponds during the summer of 1958 is given in Table 2. None of these proved to be at a level detrimental to the trout populations.

The aquatic invertebrate life in the ponds is abundant among the vegetation to depths of about 4 ft. Many species of organisms occur in the thick masses of *Chara*, most conspicuous being the larvae of *Limnephilus* (Trichoptera), *Callibaetis* (Ephemeroptera), *Hydroporus* (Coleoptera), *Physa* and *Musculium* (Mollusca), and various members of the Chironomidae. At greater depths, the only important inhabitants are chironomid larvae. Readers are referred to Ide (1930) and Ricker (1932) for more detailed information on the aquatic invertebrates.

## TROUT STOCKING DATA

Speckled trout (*Salvelinus fontinalis*), being native to the watershed, were no doubt present when the ponds were purchased by the Club in 1895. However, a planting of 50,000 fry at a cost of $3.25 per thousand fish was made in Pond C on May 7 of that year and after that time the ponds, and occasionally the creek, were stocked frequently with trout of various sizes. Only fry and fingerling trout were stocked prior to 1930. Plantings of yearling trout, when available, were preferred between 1930 and 1944. All plantings since 1944 have been with 2-year-old trout. A total of 130,800 fry, 83,000 fingerling, 17,600 yearling, and 8,850 two-year-old speckled trout have been stocked in the pond unit since 1895. Experimental plantings of 2,400 yearling rainbow trout (*Salmo gairdneri*) were made in Pond C in 1936, 1938, and 1939. The annual stocking data for the pond unit is given in Table 3.

In the earliest years of the Club, Pond A

TABLE 3.—PLANTINGS OF SPECKLED AND RAINBOW TROUT IN THE GLEN MAJOR PONDS
(F = fingerling, Y = yearling, 2Y = 2-year-old trout)

| Year | Number of *Salvelinus* | | | Year | Number of *Salvelinus* | | | |
|---|---|---|---|---|---|---|---|---|
| | Fry | Fingerlings | Yearlings | | Pond A | Pond B | Pond C | Total |
| 1895 | 50,000 | 5,000 | – | 1936 | 1,000F | 1,000F | 1,000F | 3,000F |
| 1896 | – | 5,000 | – | | 1,000Y | 700Y | 300Y | 2,000Y |
| 1897 | – | 5,000 | – | 1937 | 1,000Y | – | 1,000Y | 2,000Y |
| 1900 | – | 5,000 | – | 1938 | 500Y | 500Y | – | 1,000Y |
| 1906 | 18,000 | – | – | 1939 | 1,000Y | 500Y | – | 1,500Y |
| 1910 | – | 5,000 | – | 1940 | 1,700Y | 1,000Y | 500Y | 3,200Y |
| 1911 | – | 5,000 | – | 1942 | 1,000Y | 1,000Y | 1,000Y | 3,000Y |
| 1913 | – | 7,000 | – | 1944 | | | | 400Y |
| 1915 | – | 5,000 | – | | 600 2Y | 500 2Y | 500 2Y | 1,600 2Y |
| 1916 | – | 5,000 | – | 1946 | 600 2Y | 500 2Y | 500 2Y | 1,600 2Y |
| 1917 | – | 3,000 | – | 1950 | 400 2Y | 300 2Y | 300 2Y | 1,000 2Y |
| 1918 | – | 5,000 | – | 1951 | 700 2Y | 600 2Y | 600 2Y | 1,900 2Y |
| 1920 | 25,000 | – | – | 1953 | 500 2Y | – | 500 2Y | 1,000 2Y |
| 1921 | – | 3,000 | – | 1954 | 500 2Y | – | 250 2Y | 750 2Y |
| 1922 | 5,000 | – | – | 1955 | 400 2Y | – | 200 2Y | 600 2Y |
| 1924 | 12,800 | – | – | 1956 | 400 2Y | – | – | 400 2Y |
| 1927 | – | 5,000 | – | | | | | |
| 1928 | – | 5,000 | – | | | | | |
| 1930 | 20,000 | 5,000 | 500 | | | | | |
| 1931 | – | – | 2,000 | | Number of *Salmo Gairdneri* | | | |
| 1932 | – | – | 1,000 | | | | | |
| 1933 | – | – | 1,000 | | | | | |
| 1934 | – | 7,000 | – | 1936 | – | – | 900Y | 900Y |
| | | | | 1938 | – | – | 1,000Y | 1,000Y |
| | | | | 1939 | – | – | 500Y | 500Y |

was considered to be a rearing pond although it was fished as early as 1898. The practice was apparently to stock this pond with hatchery-reared trout and also to make use of natural reproduction there to restock Pond B; this is indicated by a notation of January 8, 1896, stating, "5,000 fingerlings were put in the nursery pond to replenish the waters after releasing the trout population into Pond B a month earlier." Following the establishment or utilization of a small pond above Pond A, which became the "nursery pond" referred to by Ricker (1932), Pond A was used for angling on the same basis as Pond B and Pond C. The redistribution of trout from pond to pond appears to have been an early management procedure. For example, on October 8, 1898, it was recorded that about half the fish in Pond A were transferred to Pond B and about half of those in the "nursery pond" into Pond A.

The stocking of hatchery-reared trout was considered to be necessary for the maintenance of fish stocks in the ponds although some natural spawning was known to occur in the tributary streams feeding the ponds. Harkness (1940) stated that "spawning areas are limited and do not appear to be particularly favourable and it is believed that the supply of catchable fish is not greatly augmented in this manner." An opportunity to evaluate the relative significance of hatchery-reared vs. naturally reproduced trout in providing angling has been made possible by the absence of plantings in any of the ponds in 1941–43, 1945, 1947–49, and 1952 and the discontinuance of plantings in Pond B after 1951, in Pond C after 1955, and Pond A after 1956. The relationship between stocking and trout harvests will be considered in a later section of this paper.

## AGE AND GROWTH OF TROUT

Speckled trout were collected for age and growth studies during the summers of

1953 and 1959. Examination of the scales reveals that the majority of trout in the ponds were under 4 yrs. of age. Only 5 of the 359 trout examined were 4 yr. old, although in recent years trout of this size range have comprised up to 10 percent of the annual harvest. Older trout, a rarity in anglers' catches, were not taken during the surveys.

Average growth curves of trout for the pond unit in 1953 and 1959 are given in Fig. 2. A comparison of these growth curves (Fig. 2a) shows a decrease in both length and weight over the interval. However, the length–weight curve (Fig. 2b) indicates no appreciable change in this relationship.

A comparison of the age–length relationship of the trout in the individual ponds (Fig. 3) reveals a significant decrease in the growth rates in Pond A and Pond C since 1953. Pond B exhibits a similar decrease in the younger age classes. In 1953, the fastest growth rate occurred in Pond A, the lowest in Pond C. Differences in growth rates are not so apparent in the 1959 analysis although Pond C continues to exhibit the slowest growth rate whereas those for Pond A and Pond B are very similar.

The observed decrease in the average growth rates of the trout in the pond unit

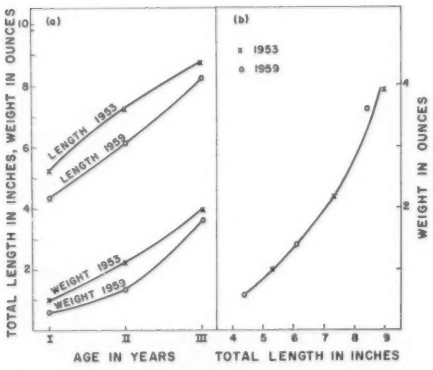


FIG. 2. Length-weight-age relationships of speckled trout from the Glen Major Pond Unit, 1953 and 1959.

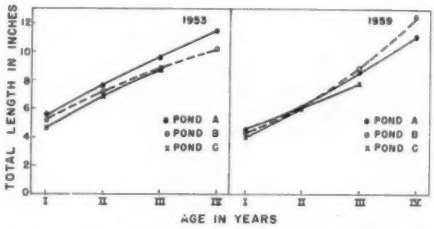


FIG. 3. Growth rates of speckled trout in each of the Glen Major ponds, 1953 and 1959.

between 1953 and 1959 would seem to fit into a trend in the fishery which is suggested by an analysis of the Club minutes and records since 1896. This analysis has revealed that the trend has been towards catches of smaller fish with increasingly fewer outstandingly large fish being harvested as the fishery progressed. Records for the 1896–1912 period report the capture of numerous fish of ¾ lb. or more in weight (e.g. on August 3, 1901, 44 trout aggregating 40 lb. were taken by one member). The harvest of large trout was not uncommon, one member catching three fish weighing 24.5, 26.0, and 29.5 oz. on opening day in 1902. The size of the record fish gradually increased to a 36-oz. trout caught in Pond A on August 5, 1910, and finally to the present Club record of a 37-oz. fish taken from Pond A on July 18, 1912. Few large fish have been taken in recent years, the largest being a 26-oz. trout taken from Pond C on May 20, 1944.

## TROUT HARVEST RECORDS

Records of the annual catches of trout by members and their guests are available since 1896, the first year of angling by the Club. These records represent the total harvest of trout from the ponds except for an unknown quantity of fish, presumedly insignificant in numbers, removed by poaching. Total annual harvests of trout for the pond unit are recorded to 1936; individual harvests for each pond are available after that time.

Since 1956, members have reported on the hours of fishing, and on the number of "legal-sized" trout caught, returned to the

water, and kept. Also, the number of "undersized" fish caught and released are recorded. The terms "legal-sized" and "undersized" refer to the 7-in. length limit formerly provided by the Special Fisheries Regulations for Ontario. Fork length measurements were used until 1954, total lengths until 1959, when the length limit on trout was abolished.

Fishing pressure has varied from year to year and, although Club membership is limited to 24 individuals (Bylaw of 1919), no more than 18 members (and their guests) have ever fished in any one year. In most years there have been no more than 15 fishing members and of these only a portion are really active in any given year.

There were no restrictions on the method of angling during the earlier years of the Club, several references being made in the records to the use of worms, minnows, grasshoppers, lures, as well as flies. However, fly fishing was the only method authorized in Pond B beginning in 1907, Pond A in 1909, and Pond C in 1925. On several occasions bait fishing has been permitted in individual ponds when fly fishing was not sufficiently rewarding. Most recently, spinning gear was permitted in Pond C during 1960 to encourage the harvest of rainbow trout, which have continued to reproduce there in small numbers since their introduction between 1936 and 1939. Approximately 450 rainbow trout have been harvested from the pond since 1937.

Harvest quotas on speckled trout were established in 1896, first by restricting angling to 10 days per member and 6 lb. of trout per day. Subsequently, annual quotas varying from 100 to 150 trout per member were adopted and remained in vogue for some years. A quota of 150 trout per member was re-established between 1948 and 1952 to overcome an abuse of fishing privilege by members. Since that time no quota has been imposed.

The annual harvests of speckled trout from 1896 to 1959 are given in Table 4.

TABLE 4.—HARVEST OF SPECKLED TROUT FROM GLEN MAJOR PONDS 1896–1959

| Year | Catch | Year | Catch | Year | Catch | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Pond A | Pond B | Pond C | Total |
| 1896 | 359 | 1917 | 874 | 1937 | 763 | 310 | 610 | 1,683 |
| 1897 | 682 | 1918 | 947 | 1938 | 947 | 281 | 571 | 1,799 |
| 1898 | 815 | 1919 | 999 | 1939 | 366 | 456 | 515 | 1,337 |
| 1899 | 885 | 1920 | 1,199 | 1940 | 400 | 414 | 268 | 1,082 |
| 1900 | 1,062 | 1921 | 903 | 1941 | 448 | 492 | 313 | 1,253 |
| 1901 | 1,064 | 1922 | 1,126 | 1942 | 398 | 333 | 353 | 1,084 |
| 1902 | 972 | 1923 | 874 | 1943 | 351 | 225 | 301 | 877 |
| 1903 | 879 | 1924 | 961 | 1944 | 357 | 379 | 273 | 1,009 |
| 1904 | 881 | 1925 | 1,158 | 1945 | 721 | 353 | 214 | 1,288 |
| 1905 | 779 | 1926 | 1,465 | 1946 | 520 | 401 | 435 | 1,356 |
| 1906 | 651 | 1927 | 1,108 | 1947 | 460 | 356 | 368 | 1,184 |
| 1907 | 893 | 1928 | 1,134 | 1948 | – | – | – | 687 |
| 1908 | 1,019 | 1929 | 916 | 1949 | 265 | 263 | 290 | 818 |
| 1909 | 308 | 1930 | 1,027 | 1950 | 418 | 324 | 0 | 742 |
| 1910 | 1,003 | 1931 | 1,218 | 1951 | 206 | 274 | 396 | 876 |
| 1911 | 1,117 | 1932 | 1,446 | 1952 | 293 | 221 | 323 | 837 |
| 1912 | 828 | 1933 | 1,238 | 1953 | 456 | 237 | 351 | 1,044 |
| 1913 | 692 | 1934 | 858 | 1954 | 393 | 347 | 232 | 972 |
| 1914 | 991 | 1935 | 1,170 | 1955 | 495 | 245 | 265 | 1,005 |
| 1915 | 884 | 1936 | 1,864 | 1956 | 611 | 277 | 333 | 1,221 |
| 1916 | 819 | | | 1957 | 665 | 364 | 437 | 1,466 |
| | | | | 1958 | 375 | 327 | 244 | 946 |
| | | | | 1959 | 476 | 388 | 212 | 1,076 |
| Total | | | | | | | | 65,710 |

Some 65,710 fish were harvested by members and their visitors during this period, representing an average annual harvest of 1,027 trout. A comparison of the harvest records by decades (1900–09: 8,508; 1910–19: 9,154; 1920–29: 10,844; 1930–39: 13,640; 1940–49: 10,638; and 1950–59: 10,185 trout) shows a gradual increase in the numbers of fish harvested up to the 1930–39 period, and a decrease thereafter. Fishing activity likewise reached a peak during the 1930–39 decade when an average of 15.6 members fished each year, an average exceeding that of the previous decades (10.7 members) and those decades following (13.8 members).

Statistics compiled on the ponds during the 1955–59 period (Table 5) allow a more satisfactory analysis of the fishery than is possible from the limited data available for previous years.

The total catch of trout reported for the pond unit during the 5-yr. period was 14,778 fish of all sizes. These were taken by 3,415 hr. of angling, representing a catch of 4.3 trout per man-hour. A comparison of total catch per unit effort from each of the ponds shows a remarkable similarity, averaging 4.3, 4.2, and 4.4 trout per man-hour in Ponds A, B, and C, respectively. Some 45.3 percent were "undersized" in Pond A, 50.4 percent in Pond B, and 59.2 percent in Pond C. These data verify the observation of anglers that catches of small fish were more of a nuisance in Pond C than in the other ponds.

TABLE 5.—TROUT HARVEST STATISTICS FOR THE POND UNIT, 1955–59

| Year | Man-hours of Fishing | Trout Caught | | | | Total | Catch Per Man-Hour | | Percentage "Sub-legal" Trout in Catch |
|---|---|---|---|---|---|---|---|---|---|
| | | "Legal" Trout | | | "Sub-legal" Trout | | | | |
| | | Caught | Returned | Kept | | | Total | Kept | |
| POND A | | | | | | | | | |
| 1955 | 188 | – | – | 495 | 311 | 806 | 4.3 | 2.6 | 38.6 |
| 1956 | 300 | 724 | 113 | 611 | 586 | 1,310 | 4.4 | 2.0 | 44.7 |
| 1957 | 362 | 886 | 221 | 665 | 600 | 1,486 | 4.1 | 1.8 | 40.4 |
| 1958 | 233 | 496 | 121 | 375 | 490 | 986 | 4.2 | 1.6 | 49.7 |
| 1959 | 290 | 623 | 147 | 476 | 688 | 1,311 | 4.5 | 1.6 | 52.4 |
| Total | 1,373 | 2,729 | 602 | 2,622 | 2,675 | 5,899 | 4.3 | 1.9 | 45.3 |
| POND B | | | | | | | | | |
| 1955 | 96 | – | – | 245 | 282 | 527 | 5.5 | 2.6 | 53.5 |
| 1956 | 134 | 321 | 44 | 277 | 326 | 647 | 4.8 | 2.1 | 50.4 |
| 1957 | 223 | 484 | 120 | 364 | 286 | 770 | 2.4 | 1.6 | 37.1 |
| 1958 | 246 | 418 | 91 | 327 | 488 | 906 | 3.7 | 1.3 | 53.9 |
| 1959 | 243 | 488 | 100 | 388 | 606 | 1,094 | 4.5 | 1.6 | 55.4 |
| Total | 942 | 1,711 | 355 | 1,601 | 1,998 | 3,944 | 4.2 | 1.7 | 50.4 |
| POND C | | | | | | | | | |
| 1955 | 124 | – | – | 265 | 321 | 586 | 4.7 | 2.1 | 54.8 |
| 1956 | 212 | 397 | 64 | 333 | 582 | 979 | 4.6 | 1.6 | 59.4 |
| 1957 | 336 | 686 | 249 | 437 | 634 | 1,320 | 3.9 | 1.3 | 48.0 |
| 1958 | 256 | 369 | 125 | 244 | 646 | 1,015 | 4.0 | 1.0 | 63.6 |
| 1959 | 172 | 271 | 59 | 212 | 697 | 968 | 5.6 | 1.2 | 72.0 |
| Total | 1,100 | 1,723 | 497 | 1,491 | 2,880 | 4,868 | 4.4 | 1.4 | 59.2 |
| TOTAL | | | | | | | | | |
| 1955 | 408 | – | – | 1,005 | 914 | 1,919 | 4.7 | 2.5 | 48.0 |
| 1956 | 646 | 1,442 | 221 | 1,221 | 1,494 | 2,936 | 4.5 | 1.9 | 50.8 |
| 1957 | 921 | 2,056 | 590 | 1,466 | 1,524 | 3,580 | 3.9 | 1.6 | 42.6 |
| 1958 | 735 | 1,283 | 337 | 946 | 1,624 | 2,970 | 4.0 | 1.4 | 54.7 |
| 1959 | 705 | 1,382 | 306 | 1,076 | 1,991 | 3,373 | 4.8 | 1.5 | 59.0 |
| Total | 3,415 | 6,163 | 1,454 | 5,714 | 7,547 | 14,778 | 4.3 | 1.7 | 51.6 |

A comparison of the size composition of the annual catch from each pond reveals a progressive increase in the percentage of small trout in Pond A and Pond C over the 5-yr. period. The number of small trout in Pond A reached only 52.4 percent, but that in Pond C increased to 72.0 percent in 1959. This trend is not apparent in Pond B where the percentage of small trout (averaging 50.4 percent) is greater than in Pond A but considerably less than in Pond C. During the 1955–59 period, 5,714 "legal-sized" trout were harvested, representing 38.7 percent of the total catch and a harvest level of 1.7 trout per man-hour.

More complete statistics for the 1956–59 period (Table 5) not only provide the total catch of "legal-sized" fish but also give a breakdown of this catch into those fish actually retained by the anglers and those returned to the water. Some 6,163 "legal-sized" trout, or 36.8 percent of the total catch of 12,792 fish of all sizes, were caught during the 4-yr. period. Of these "legal-sized" fish, 23.6 percent were rejected by the anglers and returned to the water. The 4,709 trout retained constitute the actual harvest of trout from the pond unit which were taken at a rate of 1.6 fish per man-hour of angling.

A further breakdown of the size composition of anglers' catches is made possible by detailed harvest records kept by several anglers for portions of the 1958 and 1959 seasons. In 1958, 11 members reported on 343 trout caught between June 24 and September 14. In 1959, similar records for age and growth analysis were kept by members who caught 199 trout of all sizes between June 30 and July 16.

A comparison of the size composition of the 1958 "legal-sized" catch in the three ponds revealed a distinct difference between Pond C and the other ponds. In this pond 59 percent of the catch was in the 7- to 8-in. length range in comparison to 20 percent in each of Ponds A and B. In Ponds A and B 65 percent and 69 percent, respectively, of the catch were in the 8- to 10-in. range, as contrasted to 37 percent for Pond C. Some 15 and 11 percent of the catch in Ponds A and B, respectively, were over 10 in. in length, whereas in Pond C the largest fish taken was less than 11 in. long.

A length-frequency curve for the 1959 catch shows that 75 percent of the trout were in the 5- to 8-in. range. Of the total catch, 56.3 percent were "sub-legal" and 43.7 percent "legal-sized" fish. "Sub-legal" trout made up 52.8, 48.0, and 62.0 percent of the catch in Pond A, Pond B, and Pond C, respectively. The relatively few 4- to 5-in. trout and the absence of smaller fish in the catch may be explained by the selectivity of the fishing gear, and do not represent any scarcity of young fish which may be seen in quantity in the ponds and their tributary streams. Although 7- to 8-in. fish made up between 22.4 and 27.0 percent of the total catch in each of the ponds, larger trout (over 8 in. long) constituted only 11 percent of the catch in Pond C in comparison to 24.8 and 28.0 percent, respectively, in Pond A and Pond B.

A comparison of recent trout production of the pond unit with that of the earlier years of the fishery is complicated by a difference between the present surface area of 5.1 a. and the 7.9 a. reported by Ricker (1932) and used by Harkness (1940) in his estimate of production between 1902 and 1940.

The average annual harvest for the 1896–1939 period (based on an area of 8 a.) was 129 trout per acre. That for the 1940–1959 period (based on the 5.1-a. area) was 203 trout per acre, a figure which represents annual harvests from the individual ponds averaging 230, 204, and 195 fish per acre for Ponds A, B, and C, respectively. For the 1956–59 period (Table 6) 280, 212, and 191 trout per acre were harvested annually from Ponds A, B, and C, respectively, or 231 fish per acre from the pond unit. Creek fishing was popular in the early years of the fishery, some 1,237 trout being harvested during the first decade, but this activity waned in popularity after that time.

Harkness (1940) estimated annual harvests of trout at from 41 to 131 lb. per acre for the years from 1902 to 1940. This estimate was based on a water area of 8 a.

TABLE 6.—AVERAGE ANNUAL HARVESTS OF SPECKLED TROUT PER SURFACE ACRE, 1956–59

| Pond | Area (acres) | Outflow (cu. ft./sec.) | Man-hours of Fishing | | Harvest per Acre | | Harvest per Man-hour per Acre | |
|---|---|---|---|---|---|---|---|---|
| | | | Total | per Acre | Number | Pounds | Number | Pounds |
| A | 1.9 | 5.1 | 296 | 156 | 280 | 70.5 | 1.8 | 0.45 |
| B | 1.6 | 8.4 | 212 | 133 | 212 | 51.4 | 1.6 | 0.39 |
| C | 1.6 | 10.5 | 244 | 153 | 191 | 35.6 | 1.2 | 0.23 |
| Unit | 5.1 | | 752 | 147 | 231 | 54.2 | 1.6 | 0.37 |

and an average weight of 0.5 lb. per fish harvested, both figures being at variance with recent findings. An analysis of catch statistics for the 1956–59 period (Table 6) reveals an average annual harvest of 70.5, 51.4, and 35.6 lb. per acre for each of Ponds A, B, and C, or 54.2 lb. per acre for the pond unit. During this recent period the average weight of each trout harvested has been 0.24 lb. in the upper two ponds, and 0.19 lb. in Pond C.

## DISCUSSION

A study of annual harvest levels since 1896 reveals a remarkably stable fishery in spite of changes in membership and angling habits. On only 12 occasions during the history of the fishery has the annual harvest varied as much as 25 percent from the 64-yr. average of 1,026 trout. A comparison of recent annual harvests for the pond unit, averaging 1,143 trout for the 1955–59 period, with those of the earlier years of the fishery suggests no deterioration in the availability of trout for angling.

Variations in fishing success rather than significant changes in the trout population would seem to have been a major factor in the differences in the size of annual harvests. A correlation between fishing activity, expressed as man-hours, and the numbers of trout taken by angling is apparent when these data for the 1955–59 period are analyzed. Similarly, a review of the annual fishing records from 1896 to 1959 reveals the largest catches of trout in the history of the fishery to be coincident with a peak in fishing activity during the 1930's.

A specific example of the effect of fishing activity on annual harvest levels is afforded by the decrease of 40 percent in the total harvest from 1947 to 1948. This reduction is explained largely by an annual quota of 150 trout per member imposed in 1948 which reduced the harvest of two members by some 60 percent from the preceding years, when they were responsible for about 64 percent of the total catch of the entire membership.

In view of the apparent close relationship between fishing activity and the level of annual harvests, a comparison of harvest statistics provided annually through the history of the fishery (Table 4) cannot be relied upon as a criterion of changes in the level of the trout population. The arbitrary and variable way in which anglers have selected "keeper" trout from among the "legal-sized" catch further invalidates any detailed analysis on the quality of the fishery on the basis of harvest statistics until the 1955–59 period when more detailed records were kept.

An analysis of fishing statistics for this latter period (Table 5) has shown a gradual decline in the fish harvest from 2.5 to 1.5 trout per man-hour of angling, although the catch of trout of all sizes (including those returned to the water) has remained relatively constant, averaging 4.3 fish per man-hour. This condition may be explained by changes in the percentage composition of the catch in Ponds A and C where the trend has been towards a higher percentage of "undersized" fish each year, ranging from 38.6 to 52.4 percent in Pond A and from 54.8 to 72.0 percent in Pond C between 1955 and 1959. A similar trend is not apparent in Pond B where "undersized" trout have continued to make up about 50 percent of the total catch.

A further analysis of the catch statistics reveals that the trend has been towards a higher percentage of small trout (total length less than 8 in.) and fewer large trout in the "legal-sized" catch in Ponds A and B in spite of no apparent change in the availability of trout over the past 5 years. A comparison of growth data collected in 1953 and 1959 has shown a decrease in both the average age–length and age–weight curves for the pond unit. This evidence suggests strongly that the trout produced by the pond unit are not being utilized adequately at the current level of fishing pressure and that the fish population is approaching, or has reached, a condition of overpopulation. In view of observations expressed previously on the relationship between annual harvest levels and fishing activity, it is probable that the trout population has rarely, if ever, been fully utilized.

The fact that no hatchery-reared trout have been planted in Pond A after 1951, Pond B after 1955, and Pond C after 1956 is particularly significant and points out the effectiveness of natural reproduction in providing stocks of trout. As few trout live beyond an age of 3 yr. in the pond unit, the standing trout population which has recently provided annual harvests of 231 fish, or 54.2 lb. per acre, (Table 6) must be attributed to natural reproduction. No attempt has been made here to correlate annual harvest levels with trout plantings which constituted the management policy for the ponds for over 50 years. An inadequate knowledge of the fishery would invalidate any conclusions which might be drawn.

A comparison of average 1956–59 harvest records for each of the three ponds, when expressed in terms of either numbers or pounds, reveals a progressive decrease in harvest levels from Pond A to Pond C (Table 6) which would seem to be correlated with both the linear position of the ponds on the stream system and the corresponding increase in water flow. However, if these harvest data are related to fishing activity in each of the ponds and the results expressed in terms of harvest per acre per man-hour, Pond A and Pond B are found to have similar harvests (0.45–0.39 lb.) while Pond C (0.23 lb.) lags behind.

There is further evidence to support the observed similarity between Pond A and Pond B: First, the size compositions of the respective catches show that of the total catches of fish of all sizes, "sub-legal" trout made up 52.8 and 48.0 percent, and fish over 8 in. in length 24.8 and 28.0 percent; second, the rejection rate of 22.1 and 20.8 percent of the "legal-sized" catch is similar; and third, the average weight of each trout harvested (i.e., kept by anglers) approximates 0.24 lb. in both ponds. Pond C differs in each respect with 62.0 percent of the total catch in the "sub-legal" size range, only 11.0 percent of the fish over 8 in. in length, and a rejection rate of 28.5 percent for "legal-size" trout. Also, the average weight of each trout harvested from Pond C was lowest at 0.19 lb.

Each of the ponds exhibited a decline of approximately 4 percent in the total harvest of trout per man-hour over the past 5 yr. A comparison of growth data collected in 1953 and 1959 likewise show that in each pond, with the possible exception of Pond B, the growth rate had become poorer by 1959.

All available data for the ponds suggest that in recent years, at least, the membership has not adequately harvested the abundance of small trout produced naturally in the waters. A revised management program must be implemented if the trout population is to be brought into proper balance to provide the quality of angling demanded by the membership.

## SUMMARY

A study has been made of the trout fishery of a private three-pond fishing unit of 5.1 a. for which annual stocking and harvest records are available from 1895 to 1959. During this period 65,710 fish were harvested by angling, representing a relatively stable annual harvest averaging 1,027 trout. Frequent plantings in the ponds

totalled 239,650 fry, fingerling, yearling, and 2-year-old speckled trout between 1895 and 1956. The absence of plantings in the ponds in recent years has shown no adverse effect on numbers of trout harvested.

An analysis of more detailed statistics has been made on the fishery from 1955 to 1959, when 14,778 trout of all sizes were caught by 3,007 hours of angling. Of this catch, 5,714 "legal-sized" trout, averaging 0.22 lb. each, were harvested at a rate of 1.7 fish per man-hour. The average annual harvest rate was 231 fish, or 54.2 lb. of trout per acre. During the 5-yr. period there has been a gradual decline in the annual harvest from 2.5 to 1.5 trout per man-hour although the catch of fish of all sizes has remained relatively constant, averaging 4.3 trout per man-hour. Few trout live in the ponds beyond the 4th year of life.

Available data suggest that present fishing pressure is unable to harvest adequately the abundance of trout resulting from natural reproduction. A comparison of the biology, production, and harvest of trout from each pond is included in the paper.

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## FACTORS INFLUENCING THE ZONATION OF SUBMERGED MONOCOTYLEDONS AT CEDAR KEY, FLORIDA

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Grass flats are nursery grounds for commercially important bay scallops, penaeid shrimp, and fishes. From North Carolina to New England, this habitat has been greatly reduced by disease affecting eelgrass (*Zostera marina* L.) (Stevens, *et al.*, 1950), and species dependent on eelgrass have decreased in abundance (Cottam and Munro, 1954). At Morehead City, North Carolina, the bay scallop fishery has been partially restored by the increase of *Diplanthera wrightii* (Ascherson). Along the Florida coast, the grass flats, though still extensive, are rapidly being destroyed by dredging and filling (Hutton, *et al.*, 1956). This paper, which is an enlargement of part of a master's thesis presented to the Department of Biology, University of Florida, has been prepared in the hope that it will aid those who seek to preserve the shallow-water grass flats along the Gulf Coast. Taylor (1928) gives the maximum depths at which he took seagrasses, and Humm (1956) discusses their ecology off the west coast of Florida and in the Mississippi Sound. Other data are presented by Reid (1954), Thorne (1954), Hildebrand (1958), and Guest and Gunter (1958). Since this paper was prepared for publication, Phillips (1960) has published a major paper on the seagrasses in the Tampa Bay, Boca Ciega Bay, and Tarpon Springs areas of Florida. Most of the data contained in the present paper were taken between February 1950 and June 1951 during a study of factors influencing the distribution and occurrence of the dwarf seahorse (*Hippocampus zosterae* Jordan and Gilbert) (Strawn, 1958).

I wish to thank John H. Davis, Jr., E. S. Ford, Gordon Gunter, Henry H. Hildebrand, Harold J. Humm, and Howard T. Odum for invaluable aid during this study.

### COLLECTING AREAS

The shallow waters at Cedar Key are free of surf action and support extensive grass flats. These grass flats are separated

by shallow ship channels through which water flows offshore as the tide ebbs and toward shore as the tide rises. Water drains from the grass flats into the channels during low tide and floods over the flats from the channels as the tide rises. At high tide, water flows directly across the flats. The plants growing on the flats are always exposed to a current except for brief periods at the change of the tide and in stagnant tide pools during low tide.

Collections and observations were made along three transects (collecting strips) that traversed widely separated grass flats (Fig. 1). The transects were located on flats where dwarf seahorses had been abundant in the past. Seahorses were collected with a 4-ft. wide, beveled-board pushnet. The operation of a pushnet is similar to that of a man-powered lawn mower (Strawn, 1954a). Each transect was divided into 9 to 11 stations. Length of the stations was determined by the distance a pushnet could be easily pushed, by the uniformity of the habitat, and by available landmarks. Except for Station 1 at Atsena Otie Key, only the data from stations that appeared uniform in habitat are used in this paper. Collections were made every other week during low spring tides. Low neap tides at Cedar Key were too high for the successful operation of the pushnet used in this study. Collecting was done during the day as it is difficult to isolate dwarf seahorses from trash in the net after dark. Measurements of plants were made and observations were recorded after the fishes were preserved when collecting was finished at the end of each station. Maximum leaf length of the seed plants was obtained by grasping a handful of leaves and measuring the distance from the tip of the longest leaf to the point at which this leaf emerged from the bottom deposits. Not over two or three handfuls were measured at each station.

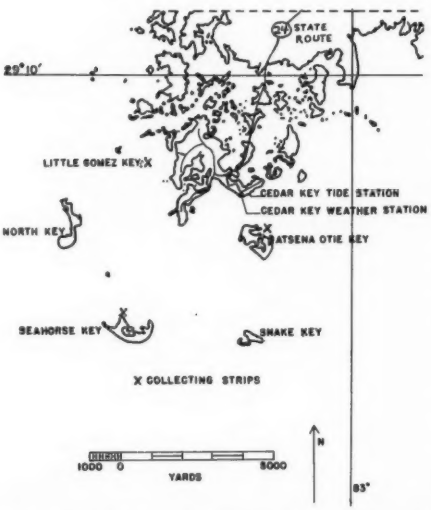


FIG. 1. Chart of the Cedar Key area. Collecting strips (transects) are indicated by X's.

Gaps in data were caused by bad weather. An 18-ft. net skiff, made of cypress and powered by a 7½-hp. motor, was used to reach the transects. Bad weather sometimes made it hazardous to cross the ship channels that lay between the transects at Atsena Otie Key and Seahorse Key and the town of Cedar Key. The period of low spring tides, during daylight, occasionally passed before it was safe to cross the long stretch of open water that lies between Cedar Key and Seahorse Key (Fig. 1).

The locations of the transects are given in Fig. 1, and maps of the stations are given in Figs. 2, 3, and 4. The transect at Atsena Otie (Fig. 2) is on a flat, a little more than a quarter of a mile wide, lying between the north side of Atsena Otie Key and the main ship channel. During low tide, a small flow of water from tidal creeks of the island drains across the east–west arm of the transect.

The collecting strip at Seahorse Key (Fig. 3) is on a large flat which lies just north of the island. The transect has about ½-mi. of grass flat between it and the nearest channel, except for a small, shallow slough that originates southeast of the transect and drains east along the north shore of Seahorse Key. Since the completion of this study, this slough has been

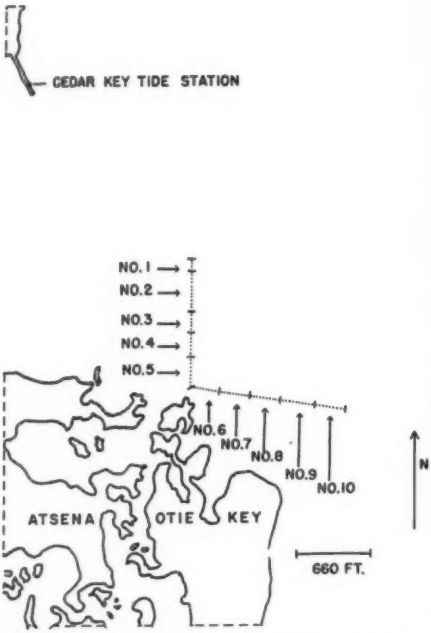


FIG. 2. Collecting stations at Atsena Otie Key.

dredged to facilitate access to The University of Florida Marine Laboratory on Seahorse Key. The transect is in a high, concave area which is dotted with large holes that are 3 to 4 ft. deeper than the level of the surrounding flat. The bottoms of these holes are sandy and are devoid of seed plants. Very little water drains across this strip during low tides.

The third strip, near Little Gomez Key (Fig. 4), is on an extensive grass flat which extends into a large cove. During low tide, considerable water drains from the cove across much of the strip and enters a slough which marks the southern end of the strip.

## SEED PLANTS

The five phanerogams growing on the grass flats at Cedar Key are *Diplanthera wrightii* (Ascherson); widgeon grass (*Ruppia maritima* L.); *Halophila engelmanni* Ascherson; turtle grass (*Thalassia testudinum* König); and manatee grass (*Syringodium filiforme* Kützing). *D. wrightii*, *T. testudinum*, and *S. filiforme* are the dominant plants of the grass flats. *H. engelmanni* is a low and inconspicuous plant. *R. maritima* was not observed in the spring of 1950. Its caulescent stems were common in the spring of 1951 on flats at Atsena Otie and Little Gomez keys; however, they were rare on the more offshore flat at Seahorse Key. *R. maritima* is recognized as an indicator of low salinities (Humm, 1956; Guest and Gunter, 1958) and will not set seed (Bourn, 1935) at salinities above 28 parts per thousand, a salinity frequently exceeded at Cedar Key. Perhaps its abundance in the spring of 1951 is correlated with the hurricane of September 1950 and accompanying salinities as low as 9.2 parts per thousand. Salinity data for Cedar Key are given in Ingle and Dawson (1953), Reid (1954), and Strawn (1954b).

## TIDE AND ZONATION

The submerged angiosperms on the inshore flats at Cedar Key occur between

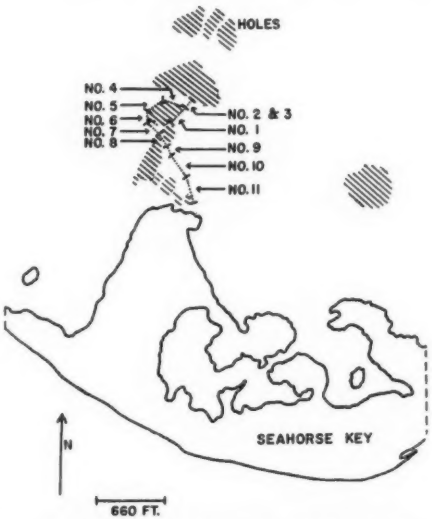


FIG. 3. Collecting stations at Seahorse Key. Striped areas indicate depressions with non-vegetated bottoms 3 to 4 ft. deeper than the surrounding grass flat.

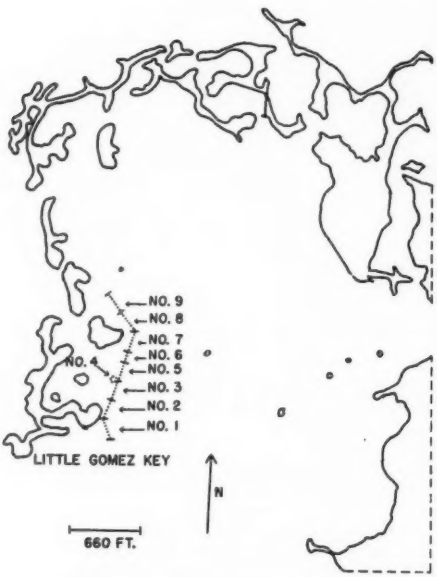


FIG. 4. Collecting stations lying just east of Little Gomez Key.

mean low water and lowest low water. Within this intertidal zone, their presence and abundance are controlled by tidal level. Turbidity may be the factor that excludes seed plants from deeper inshore areas. In clear offshore water, they grow in greater depths. Humm (1956) believes the depth of the deeper edge of *Thalassia* beds in the Mississippi Sound is determined primarily by light penetration. Desiccation prevents the occurrence of submerged seed plants on the more shallow parts of the intertidal zone. Exposure to air, especially during the winter, results in desiccation and death to parts protruding from the water. The tide at Cedar Key has a mean range of 2.5 ft. and an average spring range of 3.3 ft. (U. S. Dept. of Commerce, 1958). It is usually semidiurnal although occasionally when the moon is tropic, that is, either farthest north or south, it may become diurnal. When the moon is tropic, there is a strong diurnal inequality (Fig. 5). When the moon is equatorial, there is little diurnal inequality; the two low tides and the two high tides are similar in their respective heights (U. S. Dept. of Commerce, 1949–51).

An offshore wind lowers the level of the tide; an onshore wind raises it. The effect of an offshore wind on January 8, 1951 is shown in Fig. 5. This extremely low water occurred during a northwest wind such as often accompanies the arrival of a cold front. With the passage of the cold front, the minimum daily air temperature, recorded at the Cedar Key Weather Station, fell from 58°F. on January 7 to 29°F. on January 8.

The time of day of the lowest low water changes at the equinoxes. Fig. 5 shows a typical 15-day period of summer tide in contrast to a 15-day period of winter tide, as reconstructed from hourly levels of the Cedar Key Tide Station. Low tides are lower in the winter than in the summer. In late August, the lowest tide did not expose any of the flats on which stations were located, while in early February, all but a limited fringe of these grass flats were above the water level of the channels. The average monthly water level at Cedar Key ranged from 1.88 ft. above mean low water in August 1950 to 1.04 ft. above mean low water in February 1951—a difference of 0.84 ft. (Fig. 6). The lowest tides in the winter occur in the morning and those in the summer in the late afternoon and evening. The depth and hour of the lowest tide or tides for the 1st through the 15th and the 16th through the last of the month are given in Fig. 6.

Bimonthly percentage exposures in time, for the –0.5-ft. level and the –1.5-ft. level, were calculated from the hourly tide data of the Cedar Key Tide Station (Fig. 6). Occasions when the hourly tide data showed the tide reaching these levels, but not staying, are not included since the duration of short periods of exposure is not shown by hourly data. Plants growing on the transect at Atsena Otie Key, which is just across a ship channel from the Cedar Key Tide Station, were covered with water when the tide was at the –0.5-ft. level.

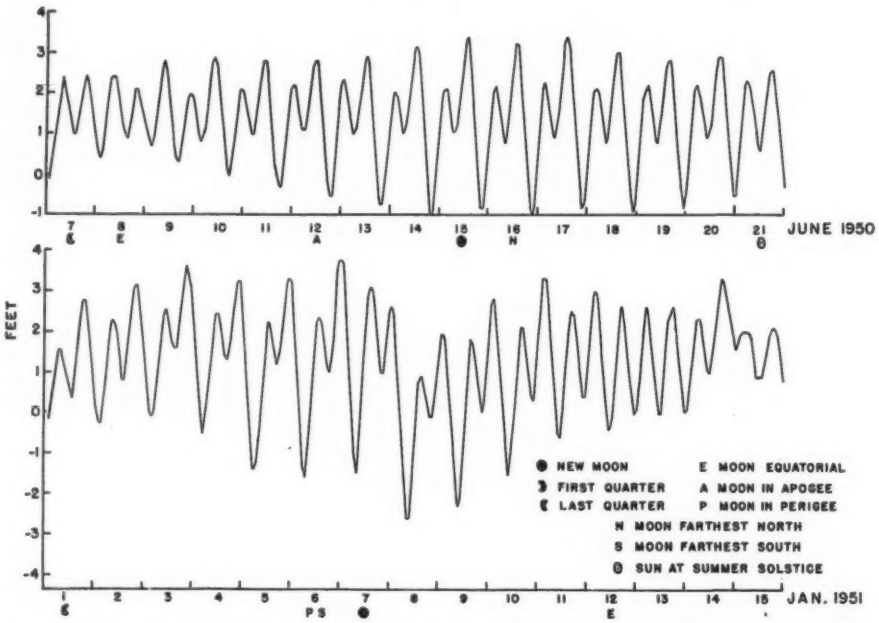


FIG. 5. Typical 15-day periods of summer and winter tide as reconstructed from hourly tide data of the Cedar Key Tide Station. Zero feet is at mean low water.

These plants, except for those growing on the deep end of Station 1 (Fig. 7), were exposed to the air when the surface of the ship channel receded to the –1.5-ft. level. Distance (Fig. 1) and differences in the time of high tide made it difficult to compare water level at the tide station with tide levels over the transects at Seahorse and Little Gomez Keys. However, it is believed that these transects were either at a similar or more shallow tide level than the transect at Atsena Otie Key.

Tides of –1.5 ft. or lower, with the exception of storm tides, usually occur between the autumnal and vernal equinoxes (Fig. 6). The lowest low waters for the years 1939–1950 were: –2.1 ft. below mean low water on February 23, 1939; –2.8, January 24, 1940; –2.5, March 14, 1941; –2.0, January 16 and February 14, 1942; –3.0, January 5, 1943; –2.8, November 19, 1944; –2.5, December 17 and 20, 1945; –2.5, February 15, 1946; –4.6, September 18, 1947; –2.5, January 26, 1948; –3.3, August 27, 1949; and –2.6, April 6, 1950. Winter exposure of grass flats frequently occurs when the sun is high and in a regime of continental polar air which has a low relative humidity and is associated with strong, cold north or northwest winds. Winter exposure is of greater duration than summer exposure. During spring tides that occur in winter, seed plants are desiccated and killed back to such a degree that parts of the flats with little water protection become almost bare and the cover of vegetation is much reduced on even the most protected areas. After the vegetation becomes sparse, fishes typical of marsh and sandy areas increase in abundance on the grass flats. Saltmarsh cyprinodonts either avoid being stranded during low tide by congregating in tide pools or by moving with the outgoing tide. They return to shallow beach and marsh

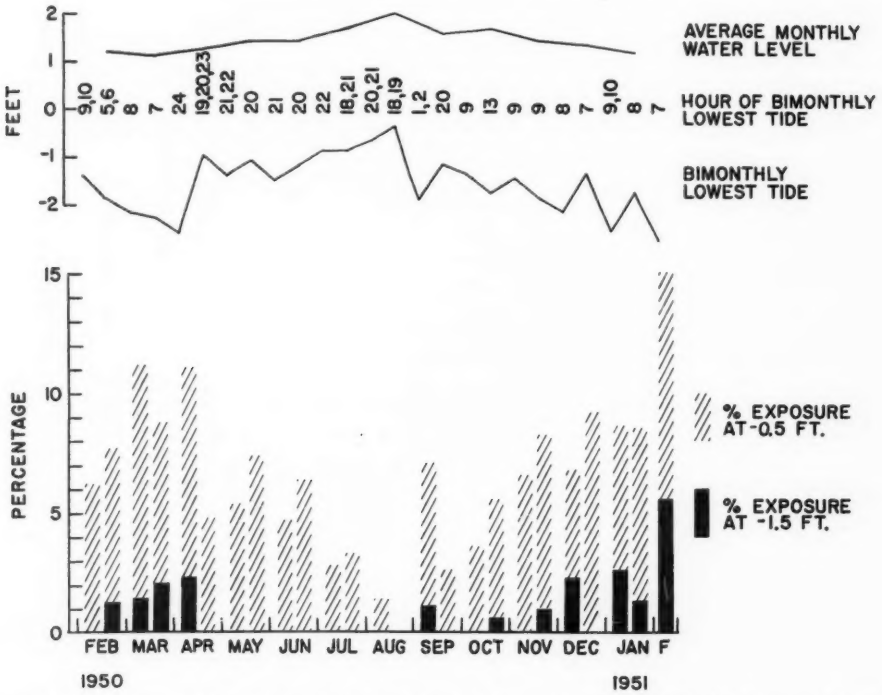


FIG. 6. Average monthly water level, time and level of lowest bimonthly tide, and the percent of the time during which the tide was either at or below –0.5 and –1.5 ft. below mean low water.

areas with the incoming tide. When the grass flats are heavily vegetated, these cyprinodonts, except for *Leucania parva* (Baird and Girard) which shows a preference for submerged vegetation, do not penetrate beyond the fringes of the grass flats. However, the environment is sufficiently changed during the winter for the cyprinodonts to follow the tide across the semi-denuded flats.

Summer exposure occurs in the late afternoon or after dark in a regime of maritime tropical air which has high relative humidity and is associated with light winds. Little desiccation occurs during the summer low spring tides and the seed plants reach their maximum abundance and leaf length. In early September, when a high percentage of exposure occurred, 22.9 of the 25.5 hours of the –0.5-ft. level or below occurred during the hurricane of September 1950. All four of the hours at –1.5 ft. or below occurred during this storm.

Even during the lowest low waters, impediments and depressions retain some water on the grass flats. This water prevents complete exposure of the flats to atmospheric conditions and protects plants from extreme desiccation. Sand bars are frequently present between channels and flats. They prevent water from taking a direct route to the channel and thus slow down movement of water off the flats. Tide pools are formed by broad concave areas, shallow vegetated holes, and deep holes with non-vegetated bottoms. These pools sometimes hold water over a foot above the level of the water in the channels. Waters from tidal creeks, oyster bars and from flats more distant from the chan-

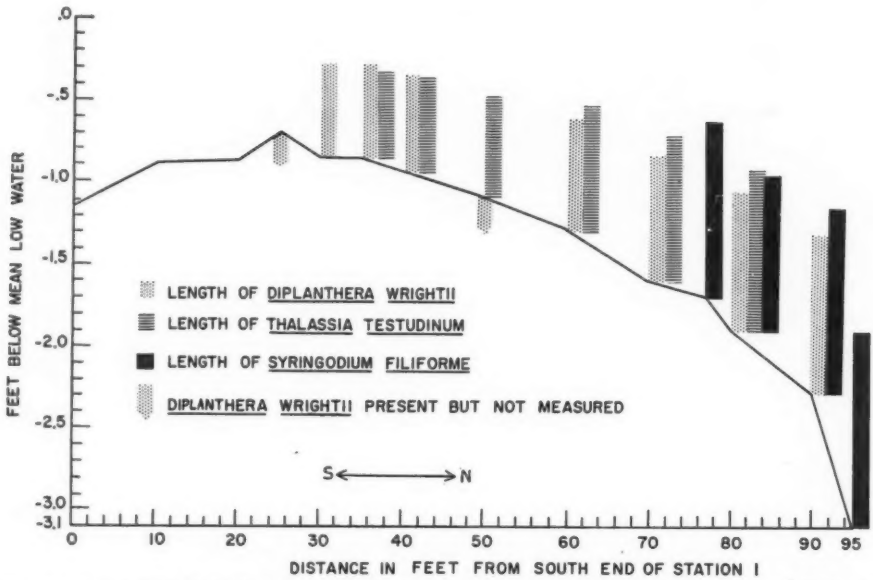


FIG. 7. Zonation of *Diplanthera wrightii*, *Thalassia testudinum*, and *Syringodium filiforme* on Station 1 at Atsena Otie Key, June 13, 1951. The south end of Station 1 (0 to 24 ft.), which is without vegetation, was a high sand bar prior to the hurricane of September 1950.

nels drain across some areas throughout the period of exposure. Consequently, these drainage areas have a greater depth of water than areas of a similar level without such drainage. In some places, the current created by the receding tide flattens leaves of the plants so that they do not protrude above the shallow water of low tide. When vegetation is thick, it greatly impedes the flow of water off the flats. Some water is retained on the flats behind elevations and in depressions made by animal activity, such as burrowing. One to two in. variation in depth can usually be found in an area of a few square feet. For the purpose of this study, water remaining on a flat above the level of the tide in the channel is called "residual water."

*D. wrightii*, *T. testudinum*, and *S. filiforme* are the conspicuous angiosperms on grass flats at Cedar Key. Their zonation is determined by leaf characteristics and by amount of protection against desiccation afforded by residual water during low tides. The stems are below the ground and only the leaves are aboveground. The selective advantages of various leaf types found on the grass flats change with the season. Deep water and summer are favorable for the dominance of plants with stiff leaves that resist being bent by the current and can extend upward toward higher light intensities. Shallow water and winter exposure are less severe on plants with flexible leaves than on plants with stiff leaves. Plants growing on narrow, relatively steep areas between channels and fringing sand bars receive little protection from residual water and are under direct influence of tidal levels. They exhibit a simple vertical zonation. This type of zonation, found on Station 1 at Atsena Otie, is presented in Fig. 7. *D. wrightii* has thin, flat, narrow leaves that can lie at right angles to the point where they emerge from the bottom and, consequently, they are safe from desiccation in very shallow water. *D. wrightii* occurs in almost pure stands on

the highest part of the vegetated slope and gradually decreases in relative abundance until on the lowest part of the slope only a few scattered plants are present. *S. filiforme*, which has relatively stiff terete leaves that protrude above the water during low tides, is found in almost a pure stand on the lowest part of the vegetated slope. It decreases in relative abundance as the water becomes shallow and exposure becomes more severe. *T. testudinum*, which has broad, flat leaves that are intermediate in stiffness and in their ability to lie at right angles to their base in shallow water, is found neither as high as *D. wrightii* nor as low as *S. filiforme*. It will survive in shallower water than *S. filiforme*. In the winter, where the three are mixed, *D. wrightii* usually has the longest, *T. testudinum* the next longest, and *S. filiforme* the shortest "living-leaf length" (the length of that portion of the leaf aboveground that is alive). *R. maritima*, which is not present on Station 1 at Atsena Otie, has a distribution similar to *T. testudinum*, although it may occur higher on the flat than *T. testudinum*. It has leaf characteristics similar to *D. wrightii*. *H. engelmanni*, which is a low, inconspicuous plant, rarely over 4 in. high, was found wherever searched for except on the highest part of the *D. wrightii* zone. It is generally too short to be exposed during low tides.

On broad flats, residual water superimposes secondary patterns on the primary pattern of vertical zonation. Except for limited areas, these flats are covered with a mixture of the three dominants. Selected stations were divided into three groups based on the protection afforded by residual water during low tide: (1) little protected, (2) protected, and (3) well protected. Little protected stations were convex, sloping, and elevated areas with little or no water draining across them at low tide. Their bottoms were hard and *T. testudinum* was more conspicuous there than *S. filiforme*. Collecting stations classified as little protected were Seahorse 2, 3, 7, and 9; Atsena Otie 3 and 4; and Little Gomez 1 and 4. Station 4 at Little Gomez Key (Fig. 2) was on an area covered with *D. wrightii*, *H. engelmanni*, and *R. maritima* and was surrounded by a mixture of these plants with *T. testudinum* and *S. filiforme*. The site of this station was a former oyster bar, and in winter the sand and shell remnants of this bar stood 1 to 2 in. higher than the surrounding flat. This slight elevation reduced the influence of residual water and permitted the type of vegetation to be determined directly by tidal level. Protected stations generally had soft bottoms and *S. filiforme* was more conspicuous on them than was *T. testudinum*. Protected stations were either in concave areas or had water draining across them during low tide. Atsena Otie 5, 8, and 9; Seahorse 9 and 10; and Little Gomez 2, 6, 7, and 8 were considered as protected. The well-protected stations had an almost pure stand of *S. filiforme* mixed with some *D. wrightii*. Stations 1, 4, 5, 6, and 8 at Seahorse Key (Fig. 3) were classified as well protected. These stations were on the sloping edges of deep tide pools. Areas with similar vegetation were present where grass flats border channels. The north end of Station 1 at Atsena Otie Key (Fig. 7) is an example.

Total lengths of leaves and maximum lengths of living parts of leaves were measured February 9, 10, and 11, 1951, at various stations where plants were considered little protected, protected, and well protected (Table 1). The greater the protection afforded by residual water, the longer was the length of the green section of the leaves. Even during seasons optimum for the growth of seed plants, an increase in either depth or residual water permits longer leaf lengths (Figs. 7 and 8). Heavy blankets of algae, which occur on some flats during the spring, may delay the recovery of seed plants from their winter low. These algae die in late May and June. Maximum development of the seed plants occurs in summer. During October and early November, many leaves are shed and a net used on the grass flats is quickly filled with dead leaves.

The zonation of submerged seed plants

TABLE 1.—RANGE IN MAXIMUM LENGTHS (one measurement per station) OF TOTAL LENGTH AND OF LIVING PORTION OF LEAVES OF DOMINANT SEED PLANTS ON GRASS FLATS AT CEDAR KEY

| Source and Length Measured | RANGE OF LENGTHS (INCHES) ON FEBRUARY 9–11, 1951 | | |
|---|---|---|---|
| | *Syringodium filiforme* | *Diplanthera wrightii* | *Thalassia testudinum* |
| Little-protected stations | | | |
| Living | 1–2 | 2–4 | 0.5–1.5 |
| Total | 3–5 | 4–8 | 3.5–7 |
| Protected stations | | | |
| Living | 2.5–6 | 5–6 | 1.5–7 |
| Total | 3–7 | 7.5–11 | 6.5–10 |
| Well-protected stations | | | |
| Living | 8–9 | 8 | |
| Total | 8–9 | 12 | |

at Cedar Key, where two low tides and two high tides a day are typical, appears to be a product of the tide curves as well as of percentage of exposure. Examples of tide curves for both summer and winter at Cedar Key are given in Fig. 5. In areas where one low and one high tide per day are of frequent occurrence, zonation within the intertidal zone is much different. At Big Lagoon southwest of Pensacola, Florida, at West Bay near San Louis Pass off the west end of Galveston Island, Texas, and on the bay side of Harbor Island west of the causeway to Port Aransas, Texas, a sharp line of demarcation occurs between *T. testudinum*, found in deeper water, and *D. wrightii*, found in shallow water. In Mosquito Lagoon, Volusia County, east coast of Florida, *T. testudinum* and *S. filiforme* are absent and *D. wrightii* occupies depths occupied by these plants in other areas.

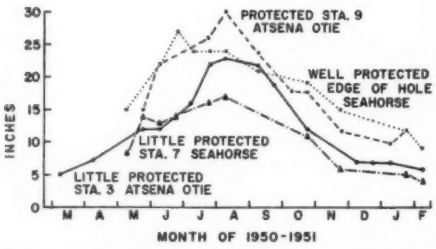


FIG. 8. Maximum lengths of leaves, species ignored, of *Diplanthera wrightii*, *Thalassia testudinum*, and *Syringodium filiforme* at various times of the year on three collecting stations and on the edge of deep holes north of Seahorse Key (Fig. 3).

## RETENTION OF SEDIMENTS BY PLANTS

The distance between mean low water and the bottom on the grass flats is controlled by an equilibrium between particle sizes of bottom deposits, ground cover provided by plants, and by the degree to which plants are covered by water during low tide. During spring and summer, the heavy growth of plants prevents currents near the bottom from reaching a velocity that will erode fine sediments, mud is deposited around the base of the plants, and the water becomes clear. In winter, few plant parts remain aboveground, finer sediments are washed away, the bottom becomes more firm, and the water is frequently turbid. On little-protected stations, cover is insufficient to prevent erosion of small particles and only sand and shell remain on the surface. During the summer, grass flats can be recognized from a distance by their dark color. They appear similar to shadows cast by clouds. During severe winters, the white color of sand exposed on the higher parts of the grass flats is conspicuous from a distance during low tide. On protected stations, desiccation is less severe and enough cover survives to retain a portion of the fine sediments. An increase in residual water favors both a soft bottom and a predominance of *S. filiforme*. Vegetation causes a gradual increase in the average height of the flat along with a general leveling. Bernatowicz (1952) found that *T. testudinum* at Bermuda forms elevations by holding accumulations of pebbles, shells, and fragments of calcareous

algae. Humm (1956) believed that *D. wrightii* tended to accumulate and hold sand. Ginsburg and Lowenstam (1958) reviewed various papers on the trapping and retention of marine sediments by plants. At Cedar Key, only sand and shell accumulate on the flats above a level which will support submerged phanerogams. Cottam and Munro (1954) reported drastic changes in the bottoms of some bays following the disappearance of *Z. marina*. Shifting sand replaced well-anchored organic soil.

A gap in ground cover occurs at Cedar Key between the most shallow intertidal level at which submerged seed plants will grow and the deepest occurrence of oyster bars, black mangroves (*Avicennia nitida* Jacq.), a few red mangroves (*Rhizophora mangle* L.), and *Spartina alterniflora* Lois. Oysters prosper when placed on either this bare level or on the grass flats, but are soon devoured by predators. Mangroves can fill this gap in southern Florida (Davis, 1940), but the tidal range is too great for them to become established at Cedar Key. This bare level is subject to erosion during hurricanes. The southern end of Station 1 at Atsena Otie Key consisted of a high, non-vegetated sand bar prior to the Cedar Key hurricane of September 1950. The storm eroded this sand bar into a depression (Fig. 7). Two years later this trough was vegetated. The vegetated north end of Station 1 was not visibly altered. This contrast in erosion between vegetated and bare areas held true wherever observations were made. However, when questioned about storm damage to grass flats, local commercial fishermen said some vegetation was uprooted off Snake Key (Fig. 1). Stabilization of the bottom during hurricanes is one of the major benefits derived from grass flats. During the hurricane season, the plants are vigorous and provide a thick ground cover. If hurricanes occurred during the winter when vegetation is sparse, the flats would probably be greatly eroded and would have a more uneven surface. Perhaps deep holes with non-vegetated bottoms, such as are found on the flat at Seahorse Key, were high sandy areas prior to a former hurricane.

Some destruction of seed plants was observed during this study. Propeller cuts, made by boats crossing flats during low water, took several months to heal. The 1950 hurricane smothered seed plants in limited areas by covering them either with sand or with blankets of algae. This storm also removed sponges, larger gastropods, starfish, sea urchins, and tunicates from the grass flats. The feet of a person wading on a grass flat uproot plants in areas with a soft bottom. The transects were traversed on foot once every two weeks. A path soon became visible in muddy areas, but no change was noted where the bottom was firm.

The area around the fill which forms the west end of Gandy Bridge, Old Tampa Bay, Pinellas County, Florida, is a major source of the dried dwarf seahorses which are commonly seen in curio shops. The seahorses are collected with pushnets (Strawn, 1954a). During 1949–52, the seahorse fishery flourished to the south of the bridge in an area of *S. filiforme* beds growing on a soft bottom. These beds were torn up and were reduced to small patches of plants by the feet of wading seahorse and bait-shrimp collectors. By 1955, the fishery moved to less accessible beds of *S. filiforme* to the north of the bridge. These beds cover a firm bottom and do not appear to be damaged by pushnetters. Except for a period following the severe winter of 1957–58, pigmy seahorse production on the north side of the bridge has been good. Springer and Woodburn (1960) believed that mud produced by dredging changed the environment to the south of the bridge. Dredging may have contributed to the removal of the dwarf seahorse fishery to the north of the bridge.

## DISCUSSION

For many years sediments have been dredged from areas supporting submerged seed plants and spewed out on either shallow grass flats or salt marshes to make land for real estate development. Spoil dredged

from channels has been piled on grass flats, making them too shallow to support submerged seed plants. Grass flats are no longer existent in the Halifax River at Daytona Beach, Florida and are scarce in parts of the Miami–Miami Beach area. The flats in the Tampa–St. Petersburg area are now being destroyed. Water is usually too deep in the dredged areas to support inshore grass flats and the areas made into land are too dry. The removal of the submerged vegetation increases erosion and turbidity. Increased turbidity decreases the recreational value of coastal areas and is detrimental to the surviving grass flats, especially their deeper parts.

Destructive dredging of grass flats is harmful to many species of economic importance and of scientific interest. Dredging eliminates the breeding grounds of the spotted sea trout (*Cynoscion nebulosus*), the most important sport fish of the shallow waters of the Gulf of Mexico and of the east coast of Florida. Grass flats are the grazing grounds of the green turtle (*Chelonia mydas* L.). The plants of the grass flats are eaten by ducks (Martin and Uhler, 1939). Along the Texas Coast duck blinds are erected on the landward side of grass flats and are excellent indicators of areas containing submerged seed plants.

Unless the destructive dredging of grass flats is stopped, many of the recreational values of the shallow waters of the Gulf of Mexico will be destroyed. Well-planned dredging should be used to enlarge existing grass flats and to restore grass flats to waters where they have been destroyed. In areas where water is now too deep to support inshore grass flats, spoil, dredged during the construction and maintenance of channels, can be used to provide depths of water optimum for the growth and survival of submerged seed plants. Dredging can be used also to lower areas that are now too shallow to support grass-flat vegetation. Effective programs for the restoration of the grass-flat habitat to areas where it has been destroyed will be dependent on a thorough knowledge of the requirements of the plants. As temperature, tidal pattern, wave action, salinity, turbidity, and quality and quantity of sediments brought in by rivers vary widely from area to area along the Gulf Coast, intensive studies should be made on the ecology of grass flats in the various coastal areas where grass flats still exist.

## SUMMARY

Five species of submerged monocotyledons occur on the grass flats at Cedar Key: *Diplanthera wrightii* (Ascherson); widgeon grass (*Ruppia maritima* L.); *Halophila engelmanni* Ascherson; turtle grass (*Thalassia testudinum* König); and manatee grass (*Syringodium filiforme* Kützing). The zonation of these plants in shallow inshore water is determined by tidal level and is modified by tide pools and by water draining across the grass flats during low tide. Plant zonation at Cedar Key, where two low and two high tides per day are of usual occurrence, differs from that found in areas where one high and one low tide per day are frequent. Plant parts exposed to air are desiccated and die. Prolonged exposure to dry, cold winds occurs during the day in winter and limited exposure to humid air occurs in the late afternoon and after sundown during summer. Shallow water and the winter environment are less severe on species with flexible leaves than on species with stiff leaves. Deeper water and summer conditions favor plants with stiff leaves.

The distance between the mean low water level and the bottom in grass-flat areas is controlled by an equilibrium between particle sizes of bottom deposits, ground cover provided by plants, and the depth of the water covering vegetated areas during low winter tides. Plants limit erosion of the grass flats during hurricanes.

Dredging and filling based on a thorough knowledge of the ecology of the seagrasses can be used to restore grass flats to areas where they have been destroyed and to enlarge existing grass flats.

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# THE WILDLIFE SOCIETY

## TRAINING AND EMPLOYMENT OF WILDLIFE BIOLOGISTS AND FISHERY BIOLOGISTS[1]

This report attempts to provide answers to questions most often asked by prospective students about fishery and wildlife biology. The text consists of a brief statement of the general kinds of work done by fishery and wildlife biologists, the nature and amount of college training required for certain kinds of jobs, and where employment opportunities are found. A list of source material is provided for further information. Also appended are (1) a list of institutions offering training with descriptions of degrees conferred; and (2) addresses of conservation agencies.

A recent survey indicated that there are 25 million people who fish and hunt in the United States. Each year they spend an estimated 3 billion dollars for their sport. Commercial fishing and trapping are worth additional millions annually to many people; but as a natural resource, wild animals are perhaps most important to the general public for esthetic reasons. The mere sight of an animal at home in the wild is a kind of recreation not reserved for sportsmen. It is a lifting experience for all people who are interested in their living environment.

Wild animals are part of the natural heritage of all people but many species of fish and wildlife[2] have become scarce as their haunts have been destroyed or changed by man. Some species are extinct as a result of human carelessness. More species will become extinct unless the public cooperates in guaranteeing protection and living space for them. Some animals become overabundant and at times are destructive of crops and other values. Many kinds of game and fish can be maintained at favorable levels that provide hunting and fishing for the great host of sportsmen, but at the same time these animals have great recreational value to the general public.

As our human population increases, its demands grow for places to live, for more food, and for more recreation. This means an increased need for trained biologists to manage wildlife resources. Good *management* is based upon *research*. Research facts and management measures must be explained to the general public through *information* programs. These are the three general areas (management, research, information) within which most wildlife biologists do their work and for which they must be prepared by college training.

### General Work Areas

#### *Management*

Wildlife management is usually considered to be the manipulation of land, water, plants, and animals including man to produce the desired animals for recreational use of the people. On occasion, the best management is to leave things just as they are. In its broadest sense, management is of interest to many groups, including: (1) the majority of the people who derive pleasure merely from seeing wild animals in a natural setting; (2) hunters and sport fishermen; (3) those who sell all kinds of equipment and services connected with recreation based upon wildlife; (4) those who harvest wildlife for a profit, i.e., shooting-preserve operators, trappers, commercial fishermen, etc.; (5) biologists and others with professional interests in conservation; and (6) farmers and others who suffer crop or property damage because of local concentrations of wildlife.

All human activity involving the care, protection, increase, use, or control of wild animals in their natural habitat is included in wildlife management. Within this field, clear-cut areas of interest such as the management of upland game, waterfowl, big game, furbearers, and fish are found. Within each category, the work may involve one or many kinds of activity on private or public lands or waters, or on agricultural, forest, or range lands.

Training for wildlife management requires a wide background in basic sciences (biology, chemistry, physics, mathematics, geology, soils, etc.), in cultural subjects (languages, literature, philosophy, etc.), and in social sciences (history, economics, civics, etc.). The undergraduate program should emphasize animal and plant ecology, but in our opinion it should also include a broad offering of nontechnical courses from the humanities and social sciences. An introduction to specialized subject matter (wildlife-management and technique courses) in the undergraduate curriculum is desirable to the extent necessary to meet Civil Service requirements. Concentration on specialized courses should be left to graduate work. This is discussed further under Training for Fish and Wildlife Work.

#### *Research*

Wildlife research is the steady searching out of information. It fills the blanks in our knowledge of the lives, habits, and requirements of important

[1] Prepared for students and vocational counselors by the 1958–59 Employment Committee of The Wildlife Society: O. Earle Frye, Jr., James W. Kimball, Allen T. Studholme, George J. Turner, Jr., and Charles M. Kirkpatrick, Chairman. The views expressed in this special report are those of the Committee and do not necessarily reflect those prevailing throughout The Wildlife Society.

[2] The terms "fish" and "wildlife" mean the backboned animals which interest man for sporting or commercial purposes. "Wildlife" commonly includes fish, and it is used in this sense throughout the text of the report. In Civil Service terminology, a distinction between fish and wildlife is often made.

animals. Basic research in ecology, physiology, population dynamics, behavior, anatomy, etc., exposes facts upon which management practices are founded. Applied research amounts to small-scale trial and error tests of new ideas before they are used on a wide or permanent basis—hence, some research is experimental management. Successful management depends ultimately upon research.

Research workers must be able to collect facts, interpret them in their proper perspective, and report them in clear, understandable terms. The research man is specialized for exacting work, and in preparation he should get the best possible academic training preferably in addition to several years of practical experience in field and laboratory. The school chosen by the student heading for a research career should offer training commensurate with these requirements.

*Information*

The key to all wildlife problems is the cooperation of an understanding public. The stake of the general public in wildlife resources is tremendous, far greater than most people realize. Although wildlife values in one form or another belong to all the people, human uses of land and water often destroy these values long before group action materializes to save them. Therefore, a primary objective of wildlife-information work is convincing the public that wildlife management serves the best interest of the people.

Wildlife-information work has not attracted large numbers of students perhaps because of high requirements including: (1) ability in communicative skills; (2) essential knowledge of wildlife management principles; and (3) work experience. Consequently, there are few capable men available for information work, yet expanded programs in this important activity can be expected to increase job opportunities in this area of conservation.

*Teaching* wildlife-management or conservation courses at any level is one way of disseminating information. It is a vital branch of the still incompletely developed field of wildlife conservation. College teaching should produce a continuous and ever-improved supply of potential professional workers, and effective teachers at the college level should have a broad academic background of sciences, humanities, and technical subjects, with wide experience in practical operations; and if at all possible, teachers should possess personal attitudes toward their profession that inspire respect and enthusiasm in students.

*Extension* work, probably the least developed phase of conservation programs, is an important way to arouse public interest in and acceptance of conservation principles. Extension specialists should have an understanding of land uses, economics, and teaching methods in addition to practical experience in wildlife work.

Among the 25 million licensed sportsmen in the United States, many are regular readers of outdoor magazines, books, and newspaper columns. In addition to sportsmen, many other people find interest in occasional news stories or other information on outdoor sports, recreation, and wildlife in general. Outdoor literature in various forms reaches perhaps 50 million people. This public interest in wildlife makes *outdoor writing* a means of furthering conservation education. Although newspapers are interested in outdoor copy, and outdoor magazines carry experts on their staffs, writing for these outlets is obviously limited to men, with the proper combination of wildlife and journalistic training, who can present factual material in a popular style.

*Wildlife photography* is a small but growing field with fascinating opportunities for topflight photographers in the production of TV shorts, educational films, and still shots for illustration of articles. Here, mastery of photographic techniques is the first requirement, but acquaintance with wildlife ecology is so useful that photographers interested in this field are handicapped without it. Some wildlife training is particularly desirable for those using photography in connection with writing or lecturing.

The ability to paint, draw, or sketch wildlife is valuable not only to the artist who makes his living in this manner but also to teachers, research workers, and those in conservation education. Visual aids are always useful in educational work, and a properly illustrated publication or lecture is more effective than one without illustrations.

*Law enforcement* is still another aspect of wildlife-conservation employment. To some extent, the word "enforcement" is a misnomer as applied to the work of modern conservation officers and game management agents. Nowadays the officer is more than a policeman. In addition to enforcement work, the state, provincial, or federal officer draws a wide variety of assignments connected with wildlife management, research, and information, e.g., a major function of today's state conservation officer is to give conservation information of all kinds to the public; also, the federal game agent routinely gives material assistance on waterfowl surveys and banding programs. Such diversity of duty is helped by a background in wildlife biology and conservation education which can be obtained by completing a 4-year curriculum in wildlife biology. Students interested in becoming conservation officers are advised to get their training where some work in game-law enforcement or police administration is available.

## TRAINING FOR FISH AND WILDLIFE WORK

*Qualities a Wildlife Student Should Have*

The prospective student should have a tendency to like and understand people. He should be reasonably strong and self-reliant. It goes without saying that he likes the outdoors — the plants, animals, soil, water, and weather. Competency in fieldcraft, hunting, and fishing is desirable, as is familiarity with farming, forestry, and other land

uses. (A mere love for hunting and fishing, however, is not a sufficient qualification in itself; it is not the same as an aptitude for laborious college study.)

These attributes are important, but no less important is an ability to develop a sound conservation philosophy, i.e., an ethical code and sense of esthetic values toward conservation as a whole. The student should also possess an unbiased inquiring mind, commonly called the scientific attitude. If he does not have this, his education must awaken it in him.

### *Colleges and Universities Offering Fish and Wildlife Training*

Since 1935, the management of wildlife resources has steadily gained in stature as a profession. To prepare biologists for employment by conservation agencies dealing with these resources, many American colleges and universities offer curricula in the field of conservation and management of resources. During recent years there has been an increase in the attention that these institutions give to wildlife biology. Expansion is shown in enlarged staffs, in number and variety of courses offered, in more and better laboratory facilities, in acquisition of experimental areas, in increased cooperative agreements with federal and state agencies, and by special research grants.

For the student who wants to know what schools give fish and wildlife training, a partial list is appended. If certain schools interest him, the prospective student should write to the chairmen of the departments concerned for information about entrance requirements and other details.

### *What to Look for in Staff, Courses, and Facilities*

In our profession, opinions vary as to the best framework within which wildlife training should be given. There are schools organized, as in forestry, with a curriculum designed to give the student professional training within the 4-year undergraduate period. There are also other institutions that offer professional training only at the graduate school level to students selected for their broad, undergraduate background in the natural sciences. No attempt has ever been made to rate or accredit institutions for their wildlife curricula, and we have not endeavored in this report to evaluate the two contrasting philosophies of training, both of which have able spokesmen for them in the wildlife-management agencies. In general, our committee feels that undergraduate programs emphasizing basic sciences and cultural subjects are more to be desired than those offering a wide variety of "how to" techniques and management courses. The prospective student should realize that we have not emphasized the latter point of view, which may be advocated in a special report by another committee of THE WILDLIFE SOCIETY. In choosing a school, we believe that the student can appraise it along the following lines:

1. The staff should include one or more productive teachers as measured by the enthusiasm and success of the students graduated. Research activity by staff and graduate students is an asset. Other signs of quality in a wildlife staff are regular contributions to scholarly literature, organization of seminars, and a general fostering of the scientific attitude among students.

2. Adequate course offerings should be available in zoology, botany, and ecology as well as in the physical sciences.

3. The school should own or have access to land or water areas on which advanced students can make special studies, and where management techniques can be tested or demonstrated. Demonstration areas aid the understanding of principles taught in the classroom.

4. The school must have an adequate wildlife library and reference collections of specimens, both in process of active expansion.

In brief, the student in selecting a school should first consider the quality of the faculty, courses and curricula, demonstration areas, library, and collections available. The name of the degree, local scenery, buildings, size of the institution, and enrollment are of secondary importance.

### *Undergraduate Training*

During the 4 years of undergraduate work, the student should develop a thorough foundation in the sciences basic to sound biological training, and, equally important, a broad grasp of cultural subjects. Some schools offer a major leading to a bachelor's degree in the wildlife field; in other schools an equivalent degree is available in zoology, forestry, agriculture, or some other unit. In many schools not offering specialized wildlife curricula, suitable groundwork for advanced training may be obtained through the basic courses in science and accompanying liberal arts, especially languages. If preliminary training is undertaken at one of the latter schools, it is advisable to determine in advance whether credits can be transferred to another school where one's terminal training will be taken.

In our opinion, an undergraduate degree is not a professional degree in this field simply because there is not enough time in 4 years to secure properly balanced training for work in so diverse a field. This viewpoint is not shared by all colleges and state conservation departments. The development of professional caliber is an individual matter. Obviously, degrees or years of college training do not guarantee professional preparedness.

Successful completion of an undergraduate curriculum qualifies the graduate for lower grade positions in fishery or wildlife biology if his general background and personality, beyond mere schooling, are satisfactory. The lower grade positions are usually limited to management positions involving surveys, habitat development, assistance to experienced personnel, etc.

An encouraging trend in employment for holders

of bachelors' degrees is found in the fact that some states require a college degree for full-time conservation officers. How effectively an officer represents his agency depends partly upon his personality and skill in dealing with people and partly upon his special knowledge of conservation. An officer inspires confidence and wins respect in accordance with his personality and principles. In addition to these personal characteristics, an officer needs a good background in wildlife biology and conservation education.

The use of college-trained men as enforcement officers is expected to increase. Salary levels for these positions probably will be adjusted accordingly.

*Graduate Training*

Many graduate schools offer advanced courses, seminars, and research problems in wildlife biology under the direction of experienced instructors. Such additional study leads to advanced degrees. A student having a master's degree founded upon a well-rounded academic program plus good thesis research has several options open to him according to his interests. He may go into a management position requiring an advanced degree or some years of practical experience. He may go into research work, or he may be recommended for doctoral work. In some cases a student may proceed directly to the doctorate without taking a master's degree. Research positions are usually filled by men with advanced degrees. A few positions, especially academic research and teaching at the college level, are properly reserved for holders of the doctorate.

Advanced degrees do not guarantee that a man will be successful, but his chances of succeeding are at least proportional to his training. A practical advantage in having an advanced degree is that one has more flexibility in changing jobs later.

*Importance of Communicative Skills*

The work of the wildlife biologist goes beyond the mere collecting of biological facts. He must be able to speak and write in a manner that is satisfactory to report his findings and recommendations to any audience. Hence, *proficiency in the use of the English language* is of utmost importance, regardless of the degree obtained. Unfortunately, the formal training of wildlife biologists often underrates this important area of learning. Deficiencies in English among wildlife trainees are emphasized each year by the reports of the Wildlife Society Employment Committee. In a 1957–58 poll of employers, 56 percent said that a major fault of technically trained conservation personnel was the inability to express themselves orally and in writing. (Some administrators say that writing and speaking skill in their biologists often is preferable to technical versatility.) This weakness appears to be the result of overemphasis on technical subjects at the expense of English, speech, literature, etc. A broad liberal arts approach at the undergraduate level would help correct the situation. Foreign language study should not be overlooked as an aid to the development of a high degree of literacy.

Most wildlife students need extra preparation in composition and in speech, and practice in article and report writing. The responsibility for this discipline lies with student and teacher alike. If a weakness in English goes back to secondary schooling, as it often does, much ground must be made up. Unfortunately, the completion of so many hours of English and speech courses is not proof of adequate preparation. The teacher should appraise the student's capacity for expression early in his program, before it is too late to help him.

Much effort is spent by all biologists in dealing with people rather than with things. That is why a wildlife biologist is adequately prepared only when he is competent in the use of the written and spoken word. Likewise, he should have a cultural basis for understanding people he deals with, whether he meets them individually or in groups. In other words, he must know something about public relations. Some people are born with a wonderful knack of getting along with people, and are good "salesmen" whatever their jobs are. Others have to develop this ability. The biologist needs an appreciation of the cultural background, the thought, and the basic interest of people he deals with. People are usually an important part of the biological problem on which he works. If the biologist is not a "born psychologist," a broad familiarity with history, literature, psychology, philosophy, etc., is a help.

*Temporary Work*

While the student is in school, interim employment in the field is important both as a part of the training and to permit prospective employers to evaluate the student. Temporary employment is often available for a summer, quarter, or semester. If no financial hardship results, it is possible that the practical experience will more than compensate for any delay in academic work. State and federal agencies often employ student assistants to help their experienced game and fish biologists. Some teachers believe that an apprentice period is a better time for undergraduates to learn well a few special field skills and management techniques rather than to spend precious term hours on technique courses. If no summer jobs are available in the field of conservation, the serious student is well advised to seek any outdoor job in a land-use activity, even farming, for such jobs lead to worthwhile experiences with land, water, and living things. Farming is especially recommended for freshmen from urban environments.

As a brief summary of the training requirements for wildlife biologists, the following schedule for areas of concentration with respect to each degree is recommended:

For the undergraduate degree

1. Basic sciences with emphasis upon biology.

2. Broad exposure to liberal arts subjects with special attention to languages and speech.
3. Management courses to meet the minimum requirements for Civil Service eligibility.

For the graduate degree

4. Intensive work on technical subjects, special problems, seminars, etc.
5. Training in research disciplines (collection, analysis, and presentation of data; library reference work; preparation of theses, papers, and reports).

Interim employment at any time

6. Practical experience in the outdoor environment.
7. Practice in field skills and management technique.

## EMPLOYMENT OPPORTUNITIES

The job a student takes in the field of wildlife biology hinges upon his interests, enthusiasm, capabilities, and type of training received as well as upon available jobs for which he qualifies. Since wildlife resources are a public trust, many jobs are with the state conservation agencies or with federal agencies. Many of these positions are under Civil Service and require entrance examinations. The compensation that these positions involve has recently been analyzed in detail by the National Wildlife Federation in a publication cited below. Employment in private industry and organizations is limited but seems to be increasing.

### *Federal Agencies*

Positions are found mostly in the Fish and Wildlife Service with a more limited number in the Forest Service, the National Park Service, and the Soil Conservation Service. The bachelor's degree is usually a minimum requirement with variable specified amounts of course work in biology. Depending somewhat on the degree attained in one's education, positions include wildlife research biologist, fishery research biologist, game management agent, refuge manager, wildlife management biologist, fishery management biologist, animal control biologist, park naturalist, etc.

### *State Agencies*

State conservation commissions have positions for fish and wildlife research leaders who plan and execute ecological studies and prepare reports; refuge managers and district game and fish managers who develop, administer and maintain refuges and other areas; conservation officers who patrol, enforce laws, promote good public relations, and assist in other conservation work; and information and education personnel who prepare educational material and disseminate information.

Fishery biologists find several classes of employment with state agencies. Duties include the collection of ecological data on fish, analysis of water, improvement of lakes and streams, experiments in propagation and planting of fish, creel censuses, etc.

The minimal requirement for most state jobs is the bachelor's degree with a major in wildlife or fisheries biology or management. When the job involves some kind of research, trainees with advanced degrees are usually preferred.

### *Education*

Schools offering wildlife curricula employ instructors with wildlife training, usually those with practical experience as well. Schools and other institutions also conduct fish and wildlife research requiring highly trained specialists. Employment in academic institutions is necessarily limited by the overall demand for college-trained men. The first requirements for academic positions are advanced degrees and experience.

In the field of general conservation education, it is expected that more job opportunities will be developed. An ever-expanding human population demands increasing use of natural resources of all kinds. Conservation must be championed with continuing vigor to secure the wise use of resources, and this will call for more educational effort on all fronts. Education in conservation is not now operating at full strength by any means. There is room for increased offerings at colleges and universities of conservation courses taken as cultural subjects by students not majoring in wildlife. There is also room for the teaching of conservation education in the primary and secondary schools. Adult education and extension work remain relatively undeveloped in conservation education. Outdoor and science writing, radio and TV offer limited but important opportunities for persons trained both in wildlife matters and communication.

### *Private Industry and Organizations*

During recent years, private interests have absorbed a small number of trained and experienced wildlife biologists, mostly in hunting clubs, experimental shooting preserves, and large land-holding companies such as ranches, oil, and timber companies. The work usually includes management of hunting areas, public relations, and research.

Several private electric power companies now employ fishery biologists, especially in the West in connection with salmon fishery problems. Also, a number of cities employ fishery biologists in their water departments to manage municipal water supplies for recreational fishing. In addition, there are a few private biological consulting firms, doing contract work for industries or associations, composed of fishery biologists or employing them.

## SOURCES OF INFORMATION

In the preparation of this report, the Committee has drawn freely upon facts and philosophy in

the sources listed below. Prospective students are urged to do supplementary reading in the books and journals marked with an asterisk (*).

*ALLEN, DURWARD L. 1954. Our wildlife legacy. Funk and Wagnalls, New York. 422pp.

HAMILTON, HOWARD L., *et al.* [1958.] Careers in animal biology. Amer. Soc. Zoologists. 16pp.

IOWA STATE COLLEGE. [1958.] Fish and wildlife. Information leaflet. 4pp.

*JOURNAL OF WILDLIFE MANAGEMENT. Organ of THE WILDLIFE SOCIETY, published quarterly since 1937. Available in many libraries. Subscriptions and single issues for sale by *The Executive Secretary*, THE WILDLIFE SOCIETY, 5921 Anniston Road, Bethesda 14, Maryland.

LEEDY, DANIEL L. 1954. Wildlife training and employment. Fish and Wildlife Service Wildlife Leaflet 352. 10pp.

LEOPOLD, ALDO, *et al.* 1939. Academic and professional training in wildlife work. J. Wildl. Mgmt., 3:156–161.

NATIONAL ASSOCIATION OF BIOLOGY TEACHERS. 1954. Training the conservation worker. A symposium appearing in the Bulletin of the American Institute of Biological Sciences dated January 1954, and consisting of the following papers:

O. F. HALL. Resource management emphasis in training technical foresters. P. 21.

ROBERT A. MCCABE. Training in wildlife management. P. 22.

KARL F. LAGLER. Preparation for fishery research and management. P. 23.

WILLIAM H. MARSHALL. Necessity for background in the training of the conservation worker. Pp. 23–24.

RICHARD L. WEAVER. Preparing teachers of conservation. Pp. 24–25.

*NEAL, HARRY E. 1956. Nature's guardians. J. Messner, Inc., N. Y. 192pp.

SIGLER, WILLIAM F. 1956. Wildlife law enforcement. Wm. C. Brown Co., Dubuque, Iowa. 342pp.

*NATIONAL WILDLIFE FEDERATION. 1960. Compensation in the fields of fish and wildlife management (salary schedule survey). National Wildlife Federation, 1412 Sixteenth St. N.W., Washington 6, D. C. 4 + 19pp.

*TRANSACTIONS OF THE NORTH AMERICAN WILDLIFE CONFERENCE. Published annually since 1936. Available in many libraries. For sale by The Wildlife Management Institute, 709 Wire Building, Washington 5, D. C.

## APPENDIX 1

### PARTIAL LIST OF COLLEGES AND UNIVERSITIES OFFERING TRAINING FOR FISHERY BIOLOGISTS AND WILDLIFE BIOLOGISTS

The descriptions of degrees given below are somewhat inconsistent, being shown as submitted by each school. The Committee chose not to risk inaccuracy by interpreting descriptions merely to achieve editorial uniformity. To save space, however, repetitions are avoided; e.g., B. S. in Zoology, M.S. in Zoology, Ph.D. in Zoology, as reported to the Committee, becomes B.S., M.S., Ph.D. in Zoology.

*Alabama Polytechnic Institute* (Auburn, Alabama)
School of Agriculture, Dept. of Zoology and Ent.
B.S., M.S. in Game Management; M.S. in Fisheries Management; Ph.D. in Zoology.

*Alaska, University of* (College, Alaska)
Department of Biological Sciences
B.S., M.S. (Biological Sciences)
Department of Wildlife Management
B.S., M.S. (Wildlife Management).

*Arizona, University of* (Tucson, Arizona)
Zoology Dept. except for Ph.D. in Wildlife Management which is under Plant Science Committee
B.S., M.S., Ph.D. in Wildlife Management.

*British Columbia, University of* (Vancouver, British Columbia)
Department of Zoology
B.S., M.S., Ph.D. (Zoology).

*California, University of* (Berkeley, California)
Zoology Department
A.B. (Wildlife Conservation); M.A., Ph.D. (Zoology).

*California, University of* (Davis, California)
Department of Zoology
A.B. or B.S., M.A., Ph.D. (Zoology).

*California, University of* (Los Angeles, California)
Department of Zoology
A.B., M.A., Ph.D. in Ichthyology, and in Vertebrate Zoology (degrees granted in Zoology).

*College of the Pacific* (Stockton, California)
Botany and Zoology
B.A. and B.S. in both Botany and Zoology.

*Colorado State University* (Ft. Collins, Colorado)
Department of Forest Recreation and Wildlife
B.S., M.S., Ph.D. (Fisheries Science); B.S., M.S., Ph.D. (Wildlife Management).

*Connecticut, University of* (Storrs, Connecticut)
Plant Science Department
B.S. (Agriculture); M.S. (Wildlife Management).

*Cornell University* (Ithaca, New York)
Department of Conservation
B.S. (Biological Sciences); M.S., Ph.D. in Fishery Biology; M.S., Ph.D. in Wildlife Management.

*Delaware, University of* (Newark, Delaware)
Department of Biological Sciences
M.A. or M.S., Ph.D. in Biology with concentration in Marine Biology, including Fisheries Biology.

*Florida State University* (Tallahassee, Florida)
No special curriculum but Biological Sciences gives some courses related to wildlife biology.
B.S., M.S., Ph.D. (Zoology).

*Florida, University of* (Gainesville, Florida)
Department of Biology
B.S., M.S., Ph.D. (Biology)
School of Forestry
B.S., M.S. in Forestry.

*Georgia, University of* (Athens, Georgia)
Department of Zoology
B.S. (Zoology); M.S., Ph.D. (Zoology–Ecology)
School of Forestry
B.S.F., M.S.F. (Forestry, major in Wildlife).

*Gulf Coast Research Laboratory* (Ocean Springs, Mississippi)
Gives one course in Marine Biology for seniors and graduates. Credit is given by Mississippi Southern College, Mississippi State University, and University of Mississippi.

*Hawaii, University of* (Honolulu, Hawaii)
Department of Zoology and Entomology
B.S., M.S., Ph.D. (Zoology). Undergraduates and graduates may specialize in fishery biology. Ph.D. is only in marine aspects.

*Humboldt State College* (Arcata, California)
Division of Natural Resources
B.S., M.S.

*Idaho, University of* (Moscow, Idaho)
College of Forestry
B.S., M.S. (Forestry). Majors in Wildlife Management and Fisheries Management; Ph.D. in Forest Science. Major in Wildlife Ecology and Fisheries.

*Illinois, University of* (Urbana, Illinois)
Zoology Department
B.S., M.S., Ph.D. in Zoology. Special curriculum for major in Wildlife Management and Conservation.

*Indiana University* (Bloomington, Indiana)
Department of Zoology
M.S., Ph.D. (Limnology); Limnology includes fishery biology.

*Iowa State College* (Ames, Iowa)
Department of Zoology and Entomology
B.S. in Fish and Wildlife Management; B.S. in Zoology. M.S., Ph.D. in Fishery Management; M.S., Ph.D. in Wildlife Management; M.S., Ph.D. in Ecology; in Limnology; and in specialized areas of Zoology.

*Kansas State College* (Manhattan, Kansas)
Department of Zoology
B.S., M.S. (Zoology).

*Kansas, University of* (Lawrence, Kansas)
Department of Zoology
A.B., M.A., Ph.D.

*Louisiana State University* (Baton Rouge, Louisiana)
School of Forestry
M.S. in Game Management.

*Louisville, University of* (Louisville, Kentucky)
Department of Biology
A.B. in Biology; B.S., M.S., Ph.D. in Botany or Zoology.

*Maine, University of* (Orono, Maine)
Department of Zoology (Fisheries)
M.A. (Fisheries Management)
School of Forestry (Wildlife)
B.S., M.S. (Wildlife Management).

*Maryland, University of* (College Park, Maryland)
Department of Zoology
B.S., M.S., Ph.D. (Zoology).

*Massachusetts, University of* (Amherst, Massachusetts)
Department of Forestry and Wildlife Management
Department of Zoology
B.S. (Zoology, Wildlife); Ph.D. (Zoology).

*Miami, University of* (Coral Gables, Florida)
Marine Sciences; Zoology (Icthyology)
B.S., M.S. in Zoology.

*Michigan State University* (East Lansing, Michigan)
Department of Fisheries and Wildlife
B.S., M.S., Ph.D. (Fisheries and Wildlife).

*Michigan, University of* (Ann Arbor, Michigan)
Department of Fisheries
B.S. (Natural Resources); M.S., Ph.D. (Fisheries)
Department of Wildlife Management
B.S. (Natural Resources); M.W.M. (Wildlife); Ph.D. (Wildlife).

*Minnesota, University of* (St. Paul, Minnesota)
Department of Entomology and Economic Zoology
B.S. (Fishery and Wildlife Management). Curriculum, College of Agriculture, Forestry, and Home Economics; M.S., Ph.D. (Major in Fisheries and Wildlife Management).

*Missouri, University of* (Columbia, Missouri)
Department of Zoology
B.A. in Zoology (Wildlife Conservation and Management)
B.S. in Agriculture (Wildlife Conservation and Management)
M.A., Ph.D. in Zoology.

*Northeast Missouri State Teachers College* (Kirksville, Missouri)
Division of Science and Mathematics (Zoology)
B.S. in Conservation Education.

*North Texas State College* (Denton, Texas)
Department of Biology
B.S. (Zoology); M.S. (Fisheries Biology or Limnology).

*Ohio State University* (Columbus, Ohio)
Department of Zoology and Entomology
B.S. in Agriculture with major in Wildlife Management; M.S. degree, Ph.D. degree.

*Oklahoma State University* (Stillwater, Oklahoma)
Department of Zoology
B.S., M.S., Ph.D. (Zoology–Wildlife Conservation).

*Oklahoma, University of* (Norman, Oklahoma)
Department of Zoology
M.S., Ph.D. in Zoology.

*Ontario Agricultural College* (Guelph, Ontario)
Department of Entomology and Zoology
B.S.A., M.S.A. (in Wildlife Management and in Fisheries Management).

*Oregon State College* (Corvallis, Oregon)
Department of Fish and Game Management
B.S., M.S., Ph.D. (Fisheries); (Wildlife Management).

*Pennsylvania State University* (University Park, Pennsylvania)
Department of Zoology and Entomology
M.S., Ph.D. (Zoology–Wildlife)
School of Forestry
M.S. (Forestry–Wildlife).

*Pittsburgh, University of* (Pittsburgh, Pennsylvania)
Department of Biological Sciences, Pymatuning Laboratory of Field Biology
B.S., M.S., Ph.D. in Zoology.

*Purdue University* (Lafayette, Indiana)
Department of Forestry and Conservation
B.S. in Agriculture; M.S., Ph.D. for a major in Wildlife Management.

*Rhode Island, University of* (Kingston, Rhode Island)
Department of Zoology
B.S. (Zoology) Ecology major
Narrangansett Marine Laboratory
M.S. (Fishery Biology); Ph.D. (Biological Oceanography).

*Sacramento State College* (Sacramento, California)
Division of Science and Mathematics
B.S. and M.S. (Major in Biological Conservation with specialization in Wildlife or Fisheries Management).

*San Diego State College* (San Diego, California)
Department of Zoology
B.A. or B.S. in Life Science or Zoology; M.S. in Biology (Fishery Biology).

*Scripps Institution of Oceanography, University of California* (La Jolla, California)
Department of Marine Biology
M.S., Ph.D. (Marine Biology); M.S., Ph.D. (Biological Oceanography); M.S., Ph.D. (Zoology), the latter administered by Dept. of Zoology, UCLA, the advanced study and dissertation research being done at Scripps Institution.

*Southern Illinois University* (Carbondale, Illinois)
Department of Zoology
B.S., M.S., M.A., Ph.D. (Zoology) with specialties in both Game Management and Fishery Management.

*Stanford University* (Palo Alto, California)
Department of Biological Sciences
B.A., M.A., Ph.D. are given in Biology. No special degrees given in fisheries, wildlife management, etc.

*Texas A. & M. College* (College Station, Texas)
Department of Wildlife Management (Two options, wildlife and fisheries)
B.S., M.S., Ph.D. (Wildlife Management).

*Toronto, University of* (Toronto, Ontario)
Department of Zoology, Faculty of Arts
B.A., M.A., Ph.D. (Zoology).

*Tulane University* (New Orleans, Louisiana)
No special curriculum. Broad, basic training in Botany and Zoology at undergraduate and graduate levels. One course each in Fishery Biology and Wildlife Management.
B.S., M.S. in Botany or Zoology; Ph.D. in Zoology.

*Utah State University* (Logan, Utah)
College of Forestry, Range and Wildlife Management
B.S. (Wildlife Management); M.S. (Fishery Management and Wildlife Management); Ph.D. (Fishery Biology and Wildlife Biology).

*Utah, University of* (Salt Lake City, Utah)
Departments of Zoology and Botany
B.S., M.S., Ph.D. in Zoology with specialties in Fisheries Biology, Limnology, Mammalogy, and Ornithology.

*Virginia Polytechnic Institute* (Blacksburg, Virginia)
Forestry–Wildlife Management Department
M.S. (Wildlife Management); Ph.D. (Biology or Wildlife Management).

*Washington State University* (Pullman, Washington)
Department of Zoology
B.S. (Conservation); B.S., M.S. (Wildlife Management); B.S., M.S., Ph.D. (Zoology).

*Washington, University of* (Seattle, Washington)
College of Fisheries
B.S. (Fisheries); M.S., Ph.D. (Fisheries Biology or Fisheries Technology).

*Western Michigan University* (Kalamazoo, Michigan)
Department of Biology
B.S., M.S. (Biology).

*West Virginia, University of* (Morgantown, West Virginia)
Wildlife Management curriculum in Division of Forestry
B.S. in Forestry.

*Wisconsin, University of* (Madison, Wisconsin)
Department of Forestry and Wildlife Management
M.S., Ph.D. (Wildlife Management)
Department of Zoology
M.S., Ph.D. in Zoology (Hydrobiology).

*Wyoming, University of* (Laramie, Wyoming)
Department of Zoology offers a curriculum in Wildlife Conservation and Management
B.S. (Wildlife Conservation and Management); B.S., M.S., Ph.D. (Zoology).

## APPENDIX 2

### FEDERAL, STATE, AND PROVINCIAL FISHERY AND WILDLIFE CONSERVATION AGENCIES

For a more complete and detailed list of addresses of organizations and officials concerned with wildlife and other natural resources, see,

"The Conservation Directory," available from the National Wildlife Federation, 232 Carroll Street, N.W., Washington 12, D. C., for 50 cents.

U. S. Fish and Wildlife Service, Washington 25, D. C.

Alabama: Director, Division of Game and Fish, Department of Conservation, Montgomery 4.

Alaska: Director, Department of Fish and Game, Subport Building, Juneau.

Arizona: Director, Game and Fish Commission, Arizona State Building, Phoenix.

Arkansas: Director, Game and Fish Commission, Game and Fish Building, Little Rock.

California: Director, Department of Fish and Game, 722 Capitol Ave., Sacramento 14.

Colorado: Director, Game and Fish Department, 1530 Sherman Street, Denver 2.

Connecticut: Director, Board of Fisheries and Game, State Office Building, Hartford 15.

Delaware: Director, Board of Game and Fish Commissioners, Dover.

District of Columbia: Superintendent, Metropolitan Police, Washington.

Florida: Director, Game and Fresh Water Fish Commission, 646 W. Tennessee, Tallahassee.

Georgia: Director, Game and Fish Commission, 401 State Capitol, Atlanta 3.

Hawaii: Director, Fish and Game Division, Honolulu 14.

Idaho: Director, Department of Fish and Game, 518 Front Street, Boise.

Illinois: Director, Department of Conservation, State Office Building, Springfield.

Indiana: Director, Division of Fish and Game, Department of Conservation, State Office Building, Indianapolis 9.

Iowa: Director, State Conservation Commission, East Seventh and Court Avenue, Des Moines 9.

Kansas: Director, Forestry, Fish and Game Commission, Box 581, Pratt.

Kentucky: Commissioner, Department of Fish and Wildlife Resources, Frankfort.

Louisiana: Secretary–Director, State Wildlife and Fisheries Commission, 400 Royal Street, New Orleans 16.

Maine: Commissioner, Department of Inland Fisheries and Game, State House, Augusta.

Maryland: Director, Game and Inland Fish Commission, State Office Building, Annapolis.

Massachusetts: Director, Division of Fisheries and Game, 73 Tremont St., Boston 8.

Michigan: Director, Department of Conservation, Lansing 26.

Minnesota: Commissioner, Department of Conservation, 301 Centennial Building, St. Paul 1.

Mississippi: Director, Game and Fish Commission, State Office Building, Jackson.

Missouri: Director, Conservation Commission, Farm Bureau Building, Jefferson City.

Montana: Director, Fish and Game Commission, Helena.

Nebraska: Director, Game Forestation and Parks Commission, State Capitol, Lincoln 9.

Nevada: Director, Fish and Game Commission, Box 678, Reno.

New Hampshire: Director, Fish and Game Department, 34 Bridge Street, Concord.

New Jersey: Director, Department of Conservation and Economic Development, Division of Fish and Game, 230 W. State St., Trenton 7.

New Mexico: Director, Department of Game and Fish, Santa Fe.

New York: Commissioner, Conservation Department, 1220 Washington Avenue, Albany 1.

North Carolina: Executive Director, Wildlife Resources Commission, Box 2919, Raleigh.

North Dakota: Commissioner, Game and Fish Department, Capitol Building, Bismarck.

Ohio: Chief, Division of Wild Life, Department of Natural Resources, Ohio Depts. Bldg., Columbus 15.

Oklahoma: Director, Department of Wildlife Conservation, State Capitol Building, Room 118, Oklahoma City 5.

Oregon: Director, State Game Commission, P. O. Box 4136, Portland 8; Director, State Fish Commission, 307 State Office Building, Portland 1.

Pennsylvania: Executive Director, Pennsylvania Game Commission; Executive Director, Pennsylvania Fish Commission, Harrisburg.

Rhode Island: Chief, Division of Fish and Game, Department of Agriculture and Conservation, Veterans Memorial Bldg., Providence 2.

South Carolina: Director, Wildlife Resources Department, Box 360, Columbia.

South Dakota: Director, Department of Game, Fish and Parks, State Office Building, Pierre.

Tennessee: Director, Tennessee Game and Fish Commission, Cordell Hull Bldg., Nashville 3.

Texas: Executive Secretary, Game and Fish Commission, Austin.

Utah: Director, Department of Fish and Game, 1596 West North Temple, Salt Lake City 16.

Vermont: Director, Fish and Game Service, Montpelier.

Virginia: Executive Director, Commission of Game and Inland Fisheries, P. O. Box 1642, Richmond 13.

Washington: Director, Department of Fisheries, 4015 20th Ave., Seattle 99; Director, Department of Game, 600 N. Capitol Way, Olympia.

West Virginia: Director, Conservation Commission of West Virginia, State Office Building No. 3, Charleston.

Wisconsin: Director, Conservation Department, Box 450, Madison 1.

Wyoming: State Game and Fish Commissioner, Wyoming Game and Fish Commission, Box 378, Cheyenne.

Puerto Rico: Chief, Section of Fisheries and Wildlife, Department of Agriculture and Commerce, Santurce.

Canada: Canadian Wildlife Service, Department of Northern Affairs and National Resources, Ottawa; Conservation and Development Service, Department of Fisheries, Ottawa.
Alberta: Director, Fish and Wildlife, Department of Lands and Forests, Edmonton.
British Columbia: Director, Fish and Game Branch, 567 Burrard Street, Vancouver.
Manitoba: Directors of Game and Fisheries Branches, Department of Mines and Natural Resources, Winnipeg.
New Brunswick: Chief, Fish and Wildlife Branch, Department of Lands and Mines, Fredericton.
Newfoundland: Director, Wildlife Division, Department of Mines and Resources, P. O. Box 127, St. Johns.
Nova Scotia: Director of Wildlife Conservation, Department of Lands and Forests, Halifax.
Ontario: Chief, Fish and Wildlife Branch, Department of Lands and Forests, Parliament Buildings, Toronto.
Prince Edward Island: Deputy Minister of Industry and Natural Resources, Charlottetown.
Quebec: General Superintendent, Department of Fish and Game, Quebec.
Saskatchewan: Directors of Wildlife and Fisheries Branches, Department of Natural Resources, Government Administration Building, Regina.

### EDITORIAL NOTE

Single copies of the Special Committee Report printed above can be secured without charge by writing to the *Executive Secretary*, THE WILDLIFE SOCIETY, C. GORDON FREDINE, 5921 Anniston Road, Bethesda 14, Maryland.

Agencies desiring to order reprints of this report in bulk should communicate directly with the Society's printer, *The Allen Press*, Lawrence, Kansas. The press will hold the type for 12 months after publication. Charges for reprints are 10¢ each for the first 100 copies; and 7¢ for each additional copy; plus postage and insurance.

## BRIEFER ARTICLES

## EXCRETED DYES USED TO DETERMINE MOVEMENTS OF COTTONTAIL RABBITS[1]

*L. N. Brown*
Department of Zoology, University of Missouri, Columbia, Missouri

A method of determining the home ranges of small mammals utilizing excreted dyes was developed and tested on *Microtus ochrogaster* (Brown and Conaway, 1961). Testing of dyes was also conducted in the laboratory and field on cottontail rabbits (*Sylvilagus floridanus*) to determine the feasibility of using excreted dyes to reveal the movements of these mammals.

Oral administration of dyes to mammals was performed by Davis, *et al.* (1948), New (1958), and Kindel (1960) to determine animal movements. This paper is the first to report the use of individual dye implants in the rabbit or other mammals. After dye pellet implantation, movements were disclosed by colored urine spots and feces on the snow.

Acknowledgment is made to Clinton H. Conaway, Department of Zoology, University of Missouri, for assistance and advice throughout this study.

[1] This investigation was partially supported by a National Science Foundation Graduate Fellowship.

### MATERIALS AND METHODS

Dye pellets that were successful in microtines (Brown and Conaway, 1961) were placed in cottontails under laboratory conditions. Dyes tested were cyanol blue, fast green, meta cresol purple, phenol red, and safranin-0. Care was taken to place dye pellets under the tougher fascia which lies beneath the thin skin of the rabbit's back. Four to six 80-mg. dye pellets 3/32 in. in diameter were placed under the skin of each rabbit. Two or three small surgical clamps closed the opening through which the dye pellets were inserted. Ether was used for an anesthetic. The animals were housed in outdoor wire-bottomed cages, and large white filter papers were placed under each cage after pellet implantation. Filter papers were changed every 24 hours until the urine no longer showed dye coloration. This experiment was designed to determine what quantity of dye pellets was required to color the urine of the cottontail rabbit for several days. The method of making dye pellets was presented by Brown and Conaway (1961).

No attempt was made to measure effect of implanted dye pellets on rabbit activity.

*C. W. Green Wildlife Research Area*

A field test of the dye pellet technique of revealing the movements of rabbits was performed with penned cottontail rabbits at the C. W. Green Wildlife Research Area (owned by the Missouri Conservation Commission), 14 mi. south of Columbia, Missouri. Three cottontail rabbits were implanted with four to six 84-mg. dye pellets on January 21, 1960. Wooden box traps were used to live-trap the animals in a 5.18-a. fenced enclosure. The enclosure was a grass-covered meadow with an oak–hickory woodlot border on two sides. Implantation of pellets was done in the field, and the rabbits were released in the enclosure. No anesthetic was used; the individuals were merely hooded during implantation. Three in. of snow at the time the test was initiated readily permitted observation of any rabbit urine spots or droppings. The enclosure was systematically surveyed on foot once each day, and dye-colored urine spots and droppings were noted and mapped. Acid and base solutions were used in the field to identify conclusively a yellow dye, meta cresol purple. It changed from yellow to purple when 10 percent KOH solution was added; the yellow-brown urine spots of unmarked rabbits were unaffected. Survey of the enclosure was stopped after 3 days because the snow melted.

The minimum area method of home range determination (Dalke and Sime, 1938; Allen, 1939; and Schwartz, 1941) was adapted to the excreted dye method. The peripheral records of urine and droppings were connected by straight lines, and the enclosed area was calculated as the "apparent" home range.

*Harold Terrill Farm*

A field test of the excreted dye technique was performed on a natural population of cottontail rabbits at the H. V. Terrill Farm, 14 mi. south of Columbia, Missouri. Box traps were set around a large brush pile. An area of about 20 a. around the brush pile contained old pasture and soybean fields crossed by a number of multiflora rose fences. The ground was covered with 6 in. of snow when the study was initiated, February 27, 1960. One rabbit was implanted with dye pellets on the first day and another on the third; a new snowstorm on the second day prevented visits to the area. The implantation procedure and weight of dye pellets used were the same as in the C. W. Green Area field test. Snow fell on 3 of the 6 days following implantation of dye pellets in the rabbits. This additional snow covered the colored feces and urine and prevented recovery of movement data on those 3 days.

The movements of a male rabbit marked with cyanol blue in two consecutive 24-hour periods were plotted. The movements revealed by a female cottontail marked with fast green were also recorded during one 24-hour period. The determination of home range boundaries was too subjective to be meaningful. Therefore, measurements of apparent range length were made instead of area calculations.

## RESULTS

Five dye pellets having a total weight of 408–500 mg. were found to color the urine 4–5 days in the case of phenol red, fast green, and cyanol blue; and 6–7 days in the case of meta cresol purple and safranin-0.

Surprisingly, the subcutaneously implanted pellets of cyanol blue and fast green colored the rabbits' feces in addition to their urine. The coloration of feces in the digestive tract is probably via the bile duct.

*C. W. Green Wildlife Research Area*

Urine spot records were recovered from all three cottontails marked with dyes. Table 1 lists the number of individual records for each animal and the apparent home ranges for the 3-day test period. Colored urine spots plus colored droppings were responsible for the high number of records found for the animal implanted with cyanol blue. No fading in color of urine or droppings was noted through the third day for any of the dye-marked rabbits.

The minimum home ranges calculated for individuals 1 and 2 were small because only a few urine spots were found, and the dyes did not mark feces. Only three urine spots were identified from animal No. 2, but live-trapping would probably not have provided even this many captures of a single individual during a 3-day period. The distribution of colored droppings and urine spots, and the outline of the apparent home ranges within the 5-a. enclosures are plotted in Fig. 1. The home range of rabbit No. 2 probably encompassed the whole east side of the enclosure.

Meta cresol purple is of limited use for marking rabbits since its excreted color falls within the color range of normal rabbit urine. All yellow urine spots encountered had to be tested with a drop of basic solution to ascertain whether or not they were marked with the dye. This was time consuming, because a number of unmarked rabbits were present in the enclosure. An orange-yellow dye which does not change color at some point in the *p*H range could not be used.

The red-pink color of safranin-0 was readily

TABLE 1.—HOME RANGES OF COTTONTAILS AS REVEALED BY DYES EXCRETED IN A 5-ACRE ENCLOSURE

| Animal No. | Dye | Excretion Records | Revealed Home Range in Acres |
|---|---|---|---|
| 1. | Safranin-0 | 5 | 0.33 |
| 2. | Meta cresol purple | 3 | 0.23 |
| 3. | Cyanol blue | 28 | 2.17 |

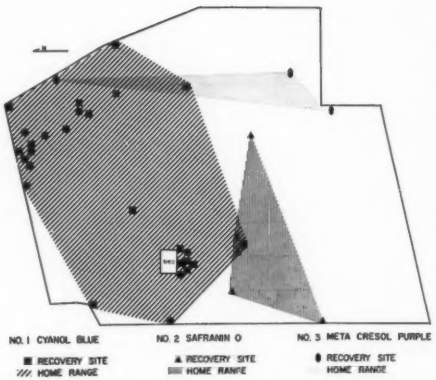


FIG. 1. Minimum home ranges of three cottontail rabbits, implanted with dye pellets, on C. W. Green Wildlife Area enclosure following a snowfall.

distinguishable from occasional spots of blood on the snow since blood spots were much more intense in color and usually smeared.

Unless ground cover vegetation is very sparse, a snow cover of less than 3 in. is probably inadequate to provide a uniform white background upon which colored urine and droppings can be seen. On one occasion, however, a bright blue urine spot of cyanol blue was located on bare soil.

*Harold Terrill Farm*

The marked rabbits followed the multiflora rose fences in most of their movements, probably because the rose brambles supplied the only good rabbit cover on much of the study area.

A total of 9 urine spots and feces records was obtained for the rabbit marked with cyanol blue in one 24-hour period and 10 in the next. Four feces records were obtained for the cottontail implanted with fast green in one 24-hour period. Fig. 2 presents the apparent ranges of movement of the two rabbits. The range lengths demonstrated by the movements of the male rabbit in each 24-hour period were 319 ft. and 470 ft. respectively. These two maximum movements were roughly at right angles on the successive nights. The marked female rabbit showed a shorter range length of 222 ft. in one 24-hour period.

No records of cyanol blue were found on the seventh day after implantation and none were found for fast green on the fourth day after implantation. The exact duration of feces and urine coloration in each case could not be determined because of fresh snowfall at critical periods during the test.

## DISCUSSION

Additional laboratory tests with other dyes would probably expand the list of dyes that successfully mark the urine and feces of rabbits when implanted subcutaneously. Dyes which mark both urine and feces have the distinct advantage of providing a greater number of identifiable records in a shorter time than those which color urine alone. In fact, dye-colored feces can be located and identified without need of the snow cover required for location of colored urine spots.

The marked rabbits on the Terrill Farm confined most of their defecation and urination to multiflora rose fences but their tracks, which could be followed when associated with colored excreta, did occasionally extend into the open. Colored urine and droppings were less frequently found in these open trails, indicating a preference for sheltered locations. It is reasonable to assume that cottontails move more slowly and stay longer in areas of cover. Thus the measure of excretion sites may not reflect the entire home range of the rabbit, although defecation and urination sites probably do tend to reveal centers of the animal's activities.

Mammals such as the swamp rabbit (*Sylvilagus aquaticus*), which repeatedly defecate at certain sites (Toll, *et al.*, 1960), could be implanted with dye pellets that mark the feces and, therefore, defecation sites. These would provide a measure of the area within which defecation sites were located and perhaps reveal the center of the actual range of the rabbit using them.

One advantage of using an excreted dye technique is that within a relatively short time a number of sites are apparent where the rabbit has been. An index to the total activity in each 24-hour period can thus be achieved.

There is a possibility that a rabbit's range of movement with a snow cover is different from

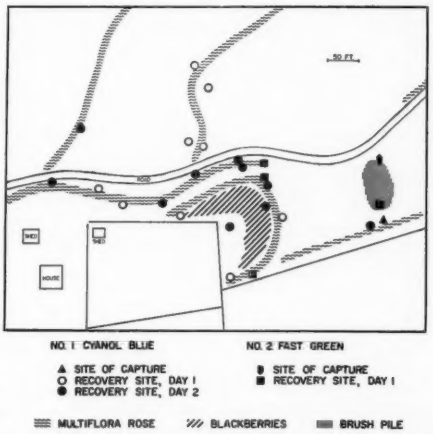


FIG. 2. Ranges of movement of two cottontail rabbits, implanted with dye pellets, on an open field area following a snowfall.

that under snow-free conditions. Additional tests should be performed to compare ranges of movement in the two situations.

SUMMARY

Five dyes known to color the urine of mice when placed subcutaneously were found likewise to color the urine of the cottontail rabbit. Laboratory experimentation indicated that from four to six 80-mg. dye pellets would color the urine from 4–7 days. Fast green and cyanol blue colored the droppings also. Field tests indicated that excreted dyes are useful in revealing the movements of cottontails when snow covers the ground. The locations of colored feces and urine depositions probably indicate centers of activity in daily movement patterns of each rabbit.

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# ANESTHETIZING DEER BY ARROW

*Carl F. Anderson*

Division of Wildlife Research, Oregon State Game Commission, Corvallis, Oregon

When paralyzing drugs (Crockford, J. A., *et al.* 1957. J. Wildl. Mgmt., 21[2]:213–220; McConnell, E. L. 1958. Norden News, 32[1]:10–11), fired from $CO_2$ guns, failed to aid effectively the capture of Columbian black-tailed deer (*Odocoileus hemionus columbianus* [Richardson]) in the rugged coast range of Oregon, personnel of the Oregon State Game Commission experimented with drug injection by means of bow and arrow. During the summer of 1959 a syringe-tipped arrow (Fig. 1) was developed that provided a simple, fast-acting, inexpensive method of anesthetizing deer at a distance of as much as 60 yd. The device, which we have called the "arrow syringe," is capable of holding 1 cc. of liquid, an amount found to be sufficient when such drugs as nicotine salicylate or succinylcholine chloride are used.

Although commercially available $CO_2$-powered guns and syringes for capturing animals met the claims of the manufacturer (Palmer Chemical and Equipment Company, Inc., Atlanta, Georgia), they often failed to immobilize deer before the animals could hide, drown, or injure themselves while falling. Ideally, the method would be best suited to use in less precipitous terrain than the coast range of Oregon. In addition, the effective range of the equipment was restricted to approximately 35 yd., and the cost of replacing the drug-carrying syringes, which were easily lost in the dense undergrowth, was prohibitive.

The arrow syringe is constructed by silver-soldering a 12-gauge hypodermic needle, reduced to three-quarters of an inch in length, into the primer pocket of a .357 magnum revolver cartridge. The open end of the cartridge case must be slightly flared in order to allow it to slide along an $11/32$-in. arrow shaft. A rubber disc, serving as a gasket, is nailed to the forward end of the arrow shaft by means of a threaded brad. Rubber discs of the proper diameter can be cut from old inner tube material by spinning an empty .357 magnum case as a "cookie cutter" in a drill press. The gasket is lubricated with a silicone grease and the syringe fitted over the end of the arrow shaft to the desired depth. The arrow syringe is loaded by injecting the required amount of drug through the 12-gauge needle with another hypodermic syringe. To prevent possible air embolism the syringe is then forced onto the shaft until the drug is visible at the open end of the 12-gauge needle. The drug is injected into the deer as the arrow shaft slides forward in the syringe when it strikes the animal.

Because of wet conditions of the blacktail habitat of Oregon, it was necessary to use rubber and plastic fletching on the arrows. For night operations the syringe and arrow shaft were marked with "Scotchlight" Brand Reflective Sheeting (Minnesota Mining and Manufacturing Company, 900 Bush Avenue, Saint Paul 6, Minnesota) to facilitate observation and to aid in locating shafts which missed the deer. The remainder of the shaft was painted pink for easier daytime recovery. In contrast to the small darts used with the $CO_2$ equipment, the larger, colored arrow syringes and shafts were usually easy to locate when a deer was

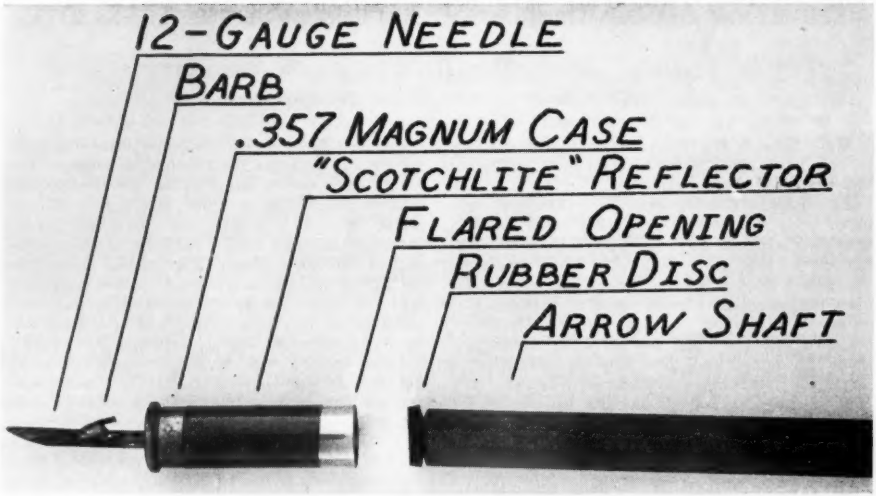


FIG. 1. Details of arrow syringe.

missed. It was found advantageous to solder onto the syringe needle a barb approximately 3 mm. in length, located 12 mm. from the tip, in order to keep syringe and arrow in the deer and thus confirm hits. This also avoids confusion when working at night.

Once the technique of making the syringes had been learned, it was possible for one person to assemble between 20 and 25 syringes in an hour. The cost of materials for each syringe was approximately 25 cents. The arrows cost the author approximately 50 cents each. Arrow shafts and syringes were re-used unless they were lost or broken.

Arrow syringes were used in combination with a 45-lb. bow to capture deer successfully at distances ranging from 2 to 60 yd. The most frequent shots were made when deer were standing approximately 40 yd. from the archer. Since much of the force from the impact was absorbed by the liquid drug being ejected from the syringe, only the syringe needle penetrated the animal's skin. Since completion of the original work, arrow syringes have been successfully tested with a 55-lb. bow.

During the testing of $CO_2$-propelled syringe, 30 seconds to several minutes often elapsed between the time when the syringe struck the deer and the time when the drug was injected. The delay was necessary to allow a chemical reaction to develop enough pressure within the syringe to drive the drug into the animal. Such a delay often provided enough time for a deer to escape before the drug began to take effect. In contrast, when the arrow syringe was used, the forward motion of the arrow shaft within the syringe body forced the liquid drug into the deer upon impact, and effects of the drug appeared within a few seconds after the animal was hit. When 400 mg. of nicotine salicylate per deer were injected with the arrow syringe into the hind quarters of 19 yearling and mature black-tailed deer, they stopped their initial frightened runs within 1 minute after being hit, and could usually be handled after 3 minutes.

The author has used the arrow syringe only 37 times on wild deer and believes that the method should be subjected to further testing. When the arrow syringe was properly planted in muscular areas of a deer, particularly the hind quarters, anesthetization was successful. Anesthetization was incomplete when the arrow syringe injected the drug into the abdominal cavity. Fatalities occurred when doses of drugs, prescribed for intramuscular administration, were injected directly into the lungs, heart, or large veins.

Obviously, the use of an arrow syringe for injecting drugs into deer and other large animals is limited by the archer's skill. Regular practice, good equipment, and the use of a rangefinder and bow sight increase accuracy. Prior to using the bow and arrow for capturing deer, the author had only a brief acquaintance with archery. Following a short period of practice, he was able to administer drugs more accurately at longer distances with a bow and arrow than with $CO_2$-powered equipment.

*Received for publication April 13, 1960.*

# SURVEY OF LEASED WATERFOWL HUNTING RIGHTS IN MINNESOTA

*Hans G. Uhlig*

Soil Conservation Service, Fergus Falls, Minnesota

Many farmers are becoming aware that the sale or lease of hunting rights may form an additional income. However, some do not know the cash value of this commodity since fixed standards have never been determined. In recent years, farmers who own wetlands have been requesting information on wetland values from soil conservationists. The information is also important because it indicates the potential value of potholes or marshes as an economic part of the farm. In some instances a known potential value may serve the farmer as a guide in determining land use or improving a marsh for production or harvest of wildlife.

Some people dislike the idea of paying for hunting rights, but there are those who feel this must be expected in the future if fish and game are to be produced and harvested on private lands. In today's era of intensive farming the aesthetic reason alone for improving wildlife habitat is no longer adequate. Many landowners feel that an economic motive should also be involved. Aldo Leopold (1933, p. 398) stated, "The only conceivable motive which might activate a sufficient number of non-shooting landholders [to manage game] is the financial motive." Berryman (1957) stated, "Even the management agencies are beginning to charge for public use on public areas, and rightly so. It is only fair that we accord the landowner similar treatment." Similar statements have been expressed by A. S. Leopold (1956), Howard and Longhurst (1956), and Smith (1960).

During 1959 an effort was made by the author to obtain information on leased waterfowl hunting rights that would serve as a guide when such information was requested of soil conservationists. Data were obtained from landowners, lessees, sheriffs, and the head of a Production Credit Association. A total of 49 leases involving 3,919 a. were checked. The total income from this source was $20,050, or an average of $409 per lease ($5.10 per acre).

Twenty of the 49 landowners received $100 or less. The average for this group was $80 per lease on an average area of 55 a. ($1.45 per acre). Seven of the remaining 29 received $101 to $200; six, $201 to $300; five, $301 to $400; and eleven over $401. The highest priced leases (over $401) averaged 118 a. or $13 per acre. Thirty hunters were involved in one lease for a total of $3,750. No leases were found for pheasant hunting only. The primary purpose of the lease was always waterfowl hunting.

In addition to the 49 leases, 7 shoreline or "waterfowl pass" leases were also recorded varying from $25 to $2,000 per year. One was leased for $2,000 per year for the next 5 years. These passes were not included in the above discussion because their vital portions involved very small areas.

Size of the area leased had little to do with the cost of the lease. Three-fifths of the leases were for 50 a. or less, and over four-fifths were for areas of 100 a. or less. In only four cases was any type of management involved and these were attempts at establishing desirable duck foods.

Local hunters were inclined to pay $10 to $75 per area at the highest. However, outside hunters, particularly those from St. Paul or Minneapolis, generally paid three to five times this amount. This factor and the farmer's knowledge, or lack of it, concerning hunting leases, appeared to determine the price of the lease. One farmer receiving $50 for a 20-acre marsh was informed of the potential, advertised, and leased the area for $150. Later he had to turn down a $300 offer.

It is believed that farmers should be informed of the potential economic as well as the aesthetic value of potholes, marshes, and other wetlands. With such information farmers may make clearer decisions regarding the "saving" of wetland areas. At present the highest priced leases ($13 per acre) give the farmer approximately the same net profit as an acre of cropland. Farmers in many counties are willing to put their cropland under the Conservation Reserve Program at the same price.

Farmers who are leasing their wetland areas for the average price of $5 per acre may find it profitable to intensify the management for waterfowl. As Leopold (1956) stated, "However, when they discover that hunting rights have a material cash value, they may somehow get around to the husbandry that is needed to amplify this value."

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# SEX DETERMINATION OF CARIBOU CALVES

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Field studies of the barren ground caribou (*Rangifer t. arcticus*) in the Canadian northland, and of the caribou (*Rangifer t. caribou*) of the Gaspé Peninsula, Quebec, have indicated an unbalanced sex ratio, favoring females (Banfield, 1954; Moisan, 1958). Annual herd composition counts of the Newfoundland subspecies (*Rangifer t. terraenovae*) conducted by me during three fall breeding seasons (1957, 1958, 1959) have revealed similar unbalanced sex ratios. In an attempt to determine the age at which differential sex mortality commences, I obtained calf sex ratios on several calving herds in 1959 as soon as possible after parturition, and continued these observations throughout the summer and fall.

On initiation of this field program, it soon became apparent that only during the first 1 or 2 days of life could young calves be caught for sex determination. Difficulty was also encountered in attempts to observe the external genitalia of the male calves, even at close range. Kelsall and Loughrey (1957) mention similar difficulties with barren ground caribou. Adequate samples could not be obtained from calves sexed according to their urinating posture. The most easily observed sex characteristic was found to be the vulva of the female calf with its tuft of long hairs. The absence of any confusing structure in the anal region of the male calf allows for ready separation between the sexes (Fig. 1).

Caribou, when alarmed, elevate their tails. This trait facilitates the observation of the female external genitalia. A calf becomes alerted upon the observation of its dam's alert behavior or upon hearing her warning grunt. Alarmed calves quickly join their dams and follow closely behind them when they retreat. Thus, slowly moving alert calves provide the best opportunity for sexing. By observation of genitalia, it was possible to sex 202 calves out of a total of 514 seen in a period of 5 days in June 1959.

FIG. 1. Two 1-week-old calves, male left, female right.

Under good viewing conditions, the vulva can be clearly seen from behind with the aid of a 20X spotting scope at distances up to 800 ft. Visual acuity is reduced on warm days by heat convection currents. On dull or windy days, ocular conditions may also be unsatisfactory for distinguishing the vulva at long ranges.

The technique is most successful when used on small caribou companies ranging from 1 to 15 adult animals accompanied by calves. When the bands are larger than this, it is desirable for the observer to cause a slight disturbance such as whistling or shouting while he is still downwind and concealed. This causes some of the more nervous does with calves to flush and allows these animals to be segregated in small subgroups as they leave the herd. When only the bold and curious does remain, the group is approached from downwind; the telescope can be carried on an extended tripod ready for immediate use when the animals turn to move off. The observer should stand upright and advance slowly in plain view of the animals. Stalking in this manner will allow more time for sexing the calves, as some of the does will hesitate before fleeing and others will move only a few yards before stopping for a second look. Quick, crouching movements should be avoided as well as the wearing of black clothing, which appears to frighten caribou more than lighter colored apparel.

The presence or absence of the vulva has also been used to sex caribou of all ages. The method is especially useful for yearlings in the spring and summer when the external genitalia of the male are still difficult to observe. During the winter season, the technique can be used to separate antlerless does from the young antlerless stags that have not yet developed the distinguishing Roman nose (Millais, 1907) of the older males.

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# SEASONAL CHANGES IN ROADSIDE ACTIVITY OF COTTONTAILS

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In an earlier finding (Lord, 1959), greater numbers of cottontail rabbits (*Sylvilagus floridanus mearnsi*) were recorded for most months of the year during roadside censuses at night rather than in early morning. The data from the above finding showed that as many or more rabbits could be seen at night than in early morning along roadsides in winter. To an extent this observation contradicts the findings of Rowe (1948) and Hendrickson and Voris (1957) who found mid-July to be the best period for observing the greatest number of rabbits along roadsides. They, however, made their censuses in the early morning, not at night. With the object of determining whether there might be seasonal changes in the time of greatest roadside activity of rabbits, a program of night-long censusing of cottontails was begun and repeated several times monthly for a year.

I am grateful to David A. Casteel for his aid in performing some of the censuses. T. G. Scott, R. E. Yeatter, C. O. Mohr, and B. A. Chipman read the manuscript critically and offered advice on its preparation. This paper is a contribution from Illinois Federal Aid Project No. 42-R, the Illinois Department of Conservation, the U. S. Bureau of Sport Fisheries and Wildlife, and the Illinois Natural History Survey, cooperating.

## Methods

A permanent, 20-mi.-long, census route was selected on the Sibley study area (Lord, 1959). The route was roughly rectangular in shape, making the start and finish at the same point. Since the route was driven at 20 m.p.h. throughout the night, every point was revisited hourly. In this way the roadside activity of the same population of rabbits was measured throughout the night. The census was begun at 4:00 p.m. and terminated at 8:00 a.m. or whenever the morning activity of rabbits ceased. Twenty censuses, distributed more or less evenly throughout the year, were performed during the period from April 1959 through March 1960. A 24-hr. census of rabbit activity was performed in June and in July of 1959 with the aid of an assistant who drove during the daylight period. During the dark the only light used to see the rabbits was the high beam of the headlights of the car. Censuses during unusually adverse weather conditions, such as prolonged rain (lasting more than 30 minutes) and snowstorms, were avoided. During the winter some rabbits were seen sitting in forms and these were not counted as active. All other rabbits seen, regardless of the nature of their activity, were counted as active.

## Results and Discussion

A total of 6,720 mi. of census route were driven, including the two 24-hr. censuses in June and July. A total of 2,971 rabbits were seen during all censuses, for an average of 0.44 rabbits per mile.

Figs. 1, 2, and 3 and Table 1 show that, regardless of changing light conditions, rabbits began their nightly activity at about 5:00 p.m. and practically ceased activity at about 7:00 a.m. Fig. 2 and Table 1 show in addition that there was a tendency for activity to begin later and more slowly in summer and continue later into the morning, but this tendency was only a slight modification of the general cycle of activity. Usually the morning peak of activity was the major one and occurred at 3:00, 4:00 or 5:00 a.m. After the morning peak, activity fell off rapidly.

In fall, the apparent irregularity of the activity pattern (Fig. 3) was probably due to the small number of rabbits seen during this season (Table 1) when rabbit roadside activity was at its lowest

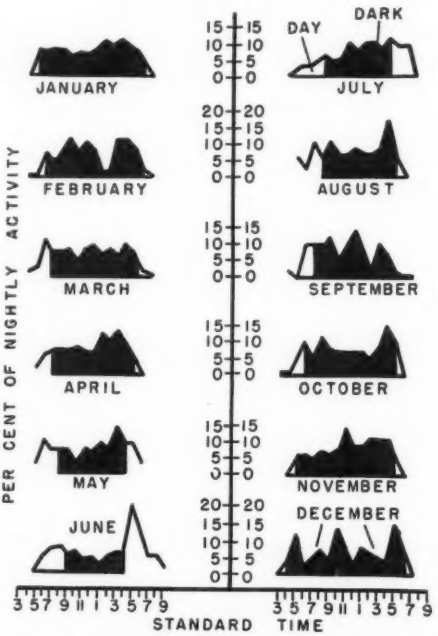


Fig. 1. Monthly activity pattern of cottontails in relation to time of day.

TABLE 1.—RESULTS OF 20 ALL-NIGHT ACTIVITY CENSUSES EXPRESSED AS PERCENT OF EACH NIGHT'S ACTIVITY

| Month | Date | Central Standard Time | | | | | | | | | | | | | | | | | Total Rabbits Seen | Rabbits per Mile |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 4–5 | 5–6 | 6–7 | 7–8 | 8–9 | 9–10 | 10–11 | 11–12 | 12–1 | 1–2 | 2–3 | 3–4 | 4–5 | 5–6 | 6–7 | 7–8 | 8–9 | 9–10 | |
| Jan. | 7/8 | 0 | 8.6 | 9.1 | 8.2 | 8.2 | 5.5 | 5.5 | 6.4 | 5.5 | 6.8 | 8.2 | 10.0 | 10.0 | 6.4 | 1.8 | 0 | – | – | 220 | 0.69 |
| | 25/26 | .5 | 5.4 | 4.0 | 6.7 | 6.7 | 5.8 | 6.3 | 4.9 | 8.1 | 12.1 | 9.0 | 10.3 | 7.2 | 7.6 | 5.4 | 0 | – | – | 223 | 0.70 |
| Feb. | 14/15 | 0 | .6 | 7.0 | 3.0 | 7.0 | 11.1 | 7.0 | 10.5 | 8.1 | .6 | 1.2 | 11.1 | 11.1 | 8.7 | 1.2 | 0 | – | – | 172 | 0.54 |
| Mar. | 13/14 | 1.5 | 2.5 | 9.5 | 5.8 | 7.6 | 7.6 | 4.0 | 8.7 | 8.7 | 7.3 | 7.3 | 6.9 | 9.5 | 11.6 | 1.5 | 0 | – | – | 275 | 0.86 |
| | 27/28 | 1.6 | 3.7 | 12.6 | 9.5 | 6.8 | 8.4 | 5.8 | 7.4 | 10.5 | 6.3 | 9.0 | 5.8 | 10.5 | 2.1 | 0 | 0 | – | – | 190 | 0.59 |
| Apr. | 7/8 | 0 | 1.3 | 2.2 | 5.2 | 5.2 | 6.5 | 12.6 | 5.2 | 9.1 | 14.3 | 8.7 | 13.4 | 17.3 | 7.4 | .4 | 0 | – | – | 231 | 0.72 |
| | 22/23 | 0 | 2.6 | 8.7 | 9.0 | 8.7 | 7.4 | 10.6 | 6.8 | 4.2 | 11.3 | 10.9 | 11.6 | 4.8 | 3.5 | 0 | 0 | – | – | 311 | 0.97 |
| May | 6/7 | 0 | 4.0 | 15.2 | 8.0 | 8.0 | 5.6 | 4.0 | 6.4 | 4.0 | 7.2 | 4.0 | 13.6 | 9.6 | 10.4 | 0 | 0 | – | – | 125 | 0.39 |
| | 21/22 | 0 | 2.0 | 7.8 | 6.4 | 6.4 | 6.8 | 2.0 | 7.1 | 7.1 | 9.2 | 8.8 | 14.6 | 8.8 | 8.1 | 4.7 | 0 | – | – | 295 | 0.92 |
| June | 15/16 | 2.6 | .9 | 5.1 | 5.1 | 6.0 | 5.1 | 6.0 | 2.6 | 6.0 | .9 | 2.6 | 8.5 | 8.5 | 19.7 | 8.5 | 5.1 | 5.1 | 1.7 | 117 | 0.37 |
| | 22/23 | 0 | 1.6 | 4.1 | 9.0 | 9.0 | 4.9 | 5.7 | 4.9 | 1.6 | 3.3 | 7.4 | 3.3 | 3.3 | 18.9 | 11.5 | 4.9 | 4.9 | 1.6 | 122 | 0.34 |
| July | 7/8 | 0 | 2.9 | 2.9 | 5.7 | 7.1 | 2.9 | 8.6 | 1.4 | 8.6 | 5.7 | 15.7 | 5.7 | 18.5 | 8.6 | 5.7 | 0 | – | – | 70 | 0.22 |
| | 20/21 | 1.5 | 2.9 | 2.9 | 2.9 | 5.1 | 4.4 | 2.9 | 13.9 | 6.6 | 11.7 | 7.3 | 8 8 | 7.3 | 8.8 | 10.9 | 2.2 | 0 | 0 | 137 | 0.43 |
| Aug. | 10/11 | 0 | 8.6 | 5.7 | 8.6 | 0 | 8.6 | 2.9 | 5.7 | 14.3 | 8.6 | 2.9 | 8.6 | 25.7 | 0 | 0 | 0 | – | – | 35 | 0.11 |
| | 26/27 | 0 | 3.7 | 0 | 11.1 | 9.3 | 11.1 | 9.3 | 7.4 | 3.7 | 5.6 | 9.3 | 7.4 | 11.1 | 9.3 | 1.9 | 0 | – | – | 54 | 0.17 |
| Sept. | 9/10 | 2.9 | 0 | 0 | 5.7 | 8.6 | 14.3 | 5.7 | 14.3 | 11.4 | 11.4 | 2.9 | 11.4 | 8.6 | 2.9 | 0 | 0 | – | – | 35 | 0.11 |
| | 22/23 | 0 | 0 | 29.4 | 17.6 | 11.6 | 5.9 | 5.9 | 0 | 17.6 | 0 | 0 | 5.9 | 5.9 | 0 | 0 | 0 | – | – | 17 | 0.05 |
| Oct. | 8/9 | 0 | 4.8 | 9.5 | 4.8 | 11.1 | 7.9 | 6.3 | 6.3 | 6.3 | 6.3 | 4.8 | 7.9 | 14.3 | 9.5 | 0 | 0 | – | – | 63 | 0.20 |
| Nov. | 9/10 | 0 | 5.0 | 5.7 | 4.3 | 6.4 | 5.7 | 7.1 | 13.6 | 8.6 | 8.6 | 10.7 | 10.0 | 10.0 | 4.3 | 0 | 0 | – | – | 140 | 0.44 |
| Dec. | 29/30 | 3.9 | 11.6 | 1.6 | 4.7 | 7.0 | 3.9 | 13.2 | 8.5 | 2.3 | 7.8 | 6.2 | 4.7 | 3.1 | 14.7 | 7.0 | 0 | – | – | 129 | 0.40 |

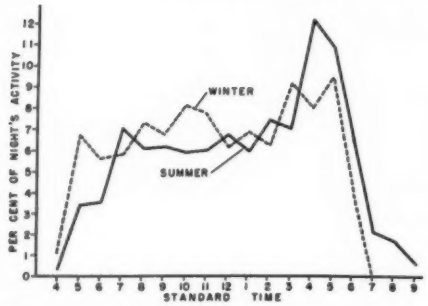


FIG. 2. Comparison of winter (Dec., Jan., and Feb.) and summer (June, July, and Aug.) roadside activity of cottontails in relation to time of day.

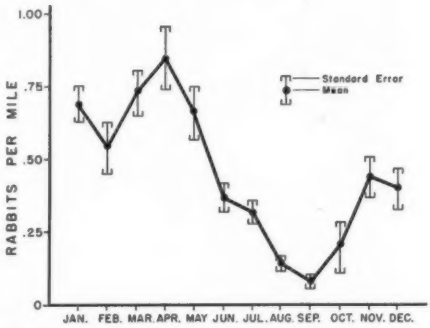


FIG. 4. Seasonal changes in the frequency of activity of cottontails along roadsides.

ebb (Fig. 4). As a general rule, any single night's activity pattern was characterized by periods of low activity producing bimodal peaks of activity as described in other mammals by Hamilton (1937), Davis (1933), Brown (1956), and Hatfield (1940), (see Fig. 1, and Table 1, October, December, and February). These periods of low activity occurred at any time after the beginning of the evening's activity and before the morning peak.

In winter, rabbit activity during the hours before midnight was approximately three-fourths the maximum intensity achieved during the early morning peak. In summer, however, the evening activity reached only about one-half the intensity of the early morning peak (Fig. 2). This would explain the findings of Rowe (1948) and Hendrickson and Voris (1957) discussed previously. Yet roadside activity of rabbits was nearly twice as intense in winter as it was in summer (Fig. 4) in spite of the fact that rabbits are three or four times more numerous in summer (Lord, 1961) than in winter. The annual cycle of roadside rabbit activity seems to be directly correlated with the sexual cycle and inversely correlated with the height of the herbaceous vegetation. This is in agreement with Haugen (1944), who found the greatest highway mortality of rabbits occurring in March and April.

In June, activity of rabbits was intensive enough at 7:00 a.m. to require continuation of the census for 2 more hours when activity ultimately reached a low level. This continuation of activity late into the morning in summer prompted the performance of the 24-hr. check of rabbit activity in both June and July. For both months, activity during the day was at the very low rate of 0.04 rabbits per mile.

The results indicated that rabbits began their nightly activity at about 5:00 p.m. and ceased at about 7:00 a.m., regardless of varying light conditions between winter and summer. There was a tendency in summer for activity to begin later and more slowly and to continue later into the morning, but this tendency was slight in comparison to the general trend.

This is in apparent contradiction to the findings of workers interested in the stimulus for onset of evening activity of nocturnal animals (DeCoursey, 1959). Perhaps this provides a basis for removing cottontails from classification as a truly nocturnal animal. Harker (1958) explains that animals may have many endogenous clocks which are geared to a 24-hr. rhythm. She also states that animals respond mainly to immediate changes in the environment, but any one factor in the environment may affect or override the others. That some factor is overriding the "sunset factor" as the stimulus for onset of activity in the cottontail rabbit is apparent. Just what this factor may be remains a question.

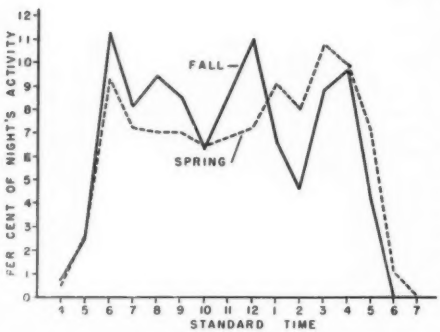


FIG. 3. Comparison of spring (Mar., Apr., and May) and fall (Sept., Oct., and Nov.) roadside activity of cottontails in relation to time of day.

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# THE QUALITY OF THE WINTER FOOD OF BLUE GROUSE

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Certain species undergo rather regular fluctuations in population density, of large amplitude, which have been called "cycles"; these include many microtine rodents, grouse, and northern hares, and predators of these herbivores. Siivonen (1954), Koskimies (1955), and much earlier, Leopold (1933) have pointed out that "cyclic" herbivores characteristically feed upon vegetative plant parts during the winter. Grouse feed on twigs, needles, buds and catkins—materials which are assumed to be of low nutritive quality. Koskimies (1955) and Lauckhart (1957) have recently focused attention on a possible correlation between the low quality of winter food and the "cyclic" nature of population fluctuations in these species.

The blue grouse (*Dendragapus obscurus*) probably belongs to this group of "cyclic" species (Hoffmann, 1956; Hartkorn, 1957; Fowle, 1960). A population of the coastal form (*D. o. sierrae*) was studied for several years at the Sage Hen Creek Project, Nevada County, California, in the Sierra Nevada. Other results of this study were reported elsewhere (Hoffmann, 1956), and the present note considers only the nutrition of the blue grouse.

The monotony of the winter diet of the blue grouse is remarkable as the diet consists almost entirely of conifer needles (Beer, 1943; Belding, 1892; Grinnell, *et al.*, 1918; Stewart, 1944). The grouse at Sage Hen Creek winter largely on needles of the white fir (*Abies concolor*). This monophagy presents the opportunity for food analysis that avoids the complexities inherent in a mixed diet.

The objective of the nutrition phase of the present study was to collect samples of needles from representative individual white fir trees, and to analyze these samples chemically. Samples were collected throughout the year, and from different heights and exposures, in order that variations in chemical quality of the needles, if any, could be detected. Any observed variation might then be correlated with the behavior of the grouse population. The samples were collected from two winter roost sites and from one tree not used as a roost, beginning in December 1951. One site (No. 15) showed intensive use the first winter, the other (No. 35) very little use. During the two winters following, the first site continued to be used heavily, while the other was not used at all. Samples were taken at first from heights of about 10 ft. and about 50 ft., on both north and south sides of the sample trees, making four samples in all. Later, the low samples were dropped. Crude protein content, determined from a selected series of samples by the Kjeldahl method, was selected as an index of nutritive quality for several reasons. Protein is the dietary factor most likely to limit maintenance and growth in the animal. Protein and digestible carbohydrate content are usually directly related. Finally, crude protein content is easily determined. Results of the analysis of needles for protein content are shown in Fig. 1. Samples taken at a height of about 50 ft. had a constant crude protein content of 6–7 percent. Samples from an elevation of about 10 ft. had a lower content, around 4–5 percent. High and low samples taken on the same date from each tree were paired, and these were subjected to a $t$ test for paired variables. The observed difference between high and low needles is strongly significant ($t = 8.43$, 12 d.f.). Protein content averaged somewhat less in needles from the north side compared with those from the south side, of trees at the same height, but a similar test showed no

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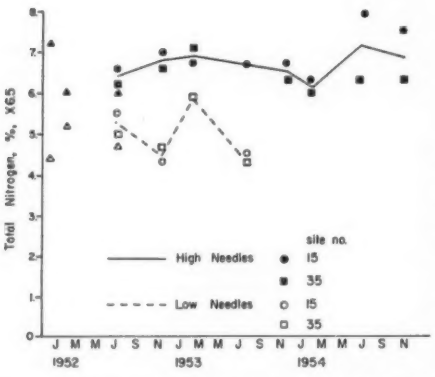


FIG. 1. Crude protein content of white fir (*Abies concolor*) needles. The "high" needles were collected about 50 ft. above the ground, the "low" needles at 10 ft. Triangles represent samples from a fir not used as a winter roost.

significant difference at the 5 percent level between these pairs of needle samples ($t = 2.23$, 7 d.f.). However, since $P$ lies between 0.1 and 0.05, additional data might disclose a more significant difference. Of more immediate importance, there is no significant annual variation in crude protein content of the trees tested (Fig. 1).

A number of roost trees were climbed and the position of branches with grouse-cropped needles was noted. In all cases, cropped needles were found only in the upper part of the trees on the winter roosts. Lindroth and Lindgren (1950) describe a similar preference for high needles in the capercaillie (*Tetrao urogallus*) in Finland. Since the needles of the higher branches are of higher protein content in the trees sampled, blue grouse may select them for that reason. However, other considerations, such as greater insolation and warmth, may play a part here, and might also explain why the birds showed some preference for the southerly sides of the upper branches. Also, more significant differences between high and low needles may exist in nutritive factors that were not measured, such as vitamin or mineral content.

The blue grouse population at Sage Hen Creek was at a high level in 1951 and in the spring of 1952. It declined abruptly, according to all evidence, in 1952, and remained at a low level through the spring of 1955 (Hoffmann, 1956). There seems, then, to be no correlation between the population trend of blue grouse and crude protein content of their winter food during the period 1951–55, and no support is lent the hypothesis that a change in food quality is related to the "cyclic" population decline in blue grouse. On the other hand, many other unmeasured nutritive factors might have been causally involved in the population decline, or the significant change in nutritive level might have occurred prior to December 1951, when needle sampling was begun.

However, the data do support the notion that blue grouse, as "cyclic" herbivores, have a winter diet of, at best, low quality but abundant quantity. The ability to subsist on a diet of the low quality provided by fir needles suggests considerable digestive efficiency of the blue grouse. This efficiency probably resides in both physiological and morphological adaptations, since Suomalainen and Arhimo (1945) have demonstrated microbial cellulase activity in the digestive tracts of several species of Finnish grouse, and Leopold (1953) has shown that grouse have "materially longer" guts than seed-eating Galliformes. The grouse caecum in particular is longer, and also shows the highest degree of cellulase activity.

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# POX IN MOURNING DOVES IN THE UNITED STATES

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The occurrence of pox-virus infection in mourning doves (*Zenaidura macroura*) has been reported from only three states: Illinois, California, and Maryland. Kossack and Hanson (1954) reported two cases of the disease from doves injured by hunters and two additional cases among mourning doves in a captive colony where the disease was introduced accidentally. Rosen (1959) and Locke, *et al.* (1960) reported two localized outbreaks that caused serious losses. Since these reports, several additional records of pox infection in the mourning dove have come to my attention. This report summarizes the present knowledge of the status of this viral disease of the mourning dove.

## Case Reports

*Alabama*—A. O. Haugen submitted a pair of feet (from a dove collected February 19, 1951, in Clarke County) to the disease laboratory of the Patuxent Wildlife Research Center. A nodule on the right foot was a 4 × 3 × 3-mm. oval thickening (measured from fixed material) at the base of the claw of the third digit. There was a line of hemorrhage at the base of the claw. The left foot had a large 9 × 4 × 3-mm. oval nodule on the 4th digit, and the claw had been lost. A nodule from the 3rd digit subjected to histological examination proved to be a typical pox nodule.

During the course of the 1950–51 trichomonad epizootic in Alabama mourning doves, S. A. Edgar, Poultry Pathologist, Auburn University (*in litt.*), isolated both pox virus and *Trichomonas gallinae* from a single diseased dove that had been collected on the campus of Auburn University.

In June 1959, I received a report of diseased mourning doves near Mobile which exhibited variable-sized nodules on the head, feet, and wings. Nodules were particularly common about the eyes. Although none of these doves could be obtained for examination, the reported nodules are typical of pox infection.

*California*—Rosen (1959) briefly discussed an outbreak of pox that occurred near Yreka, in which serious losses occurred in the infected flock.

*Florida*—Frank Winston (1951) observed that a large number of the mourning doves visiting his banding station near West Palm Beach were affected with nodular growths on their heads. He submitted a seriously infected dove to a local pathologist, who made a diagnosis of multiple papilloma of virus origin.

Winston reported that the peak of infection occurred in mid-September, when "20% of the re-trapped birds handled exhibited obvious disease symptoms. Out of 100 birds banded consecutively in mid-August, 39 were re-trapped in September. Seventeen exhibited disease symptoms when re-trapped. Three re-trapped again one and two weeks later still showed disease." The incidence dropped so that in mid-October less than 1 percent of either new or re-trapped birds showed lesions. He reported that the disease was concentrated almost entirely in birds that had been banded as juveniles in August. Five doves found diseased in September were healthy when re-trapped in mid-October.

On August 16, 1960, Winston submitted to the Patuxent Wildlife Research Center six dead juvenile mourning doves collected at West Palm Beach. Although each dove had at least one nodule on its head, usually several nodules were present. The nodules ranged from small pea-sized nodules (3–4 mm. in diameter) located on the eyelids to a large tumorous mass 10x8x5–6 mm. wide on the bill. Nodules were present on the toes of two doves. Histological sections of several nodules showed typical pox inclusion bodies.

*Illinois*—Kossack and Hanson (1954) reported four cases of pox in hunter-crippled and captive mourning doves.

*Kentucky*—A mourning dove with nodules over the entire body was shot by a hunter September 1, 1959, in Davies County. Dan Russell, Biologist, Bowling Green, removed the wing from this dove and submitted it for examination. Nodular growths on the wing proved to be pox nodules.

*Maryland*—Locke, *et al.* (1960) described a severe outbreak in a captive mourning dove flock. A single infected bird was captured September 17, 1958, on the grounds of the Agricultural Research Center, Beltsville. At the time of capture, the dove had a small pinkish nodule on the left eyelid. This nodule was excised and the cut surface was painted with tincture of merthiolate. The dove was then added to the colony.

The first dead dove in the colony was found October 5, and during the period from October 6 to November 13, 11 additional doves developed pox lesions. The most common lesions were variable-sized nodules on the head, most frequently on the eyelids. Nodules sectioned and stained for histological study contained typical pox inclusion bodies.

*Ohio*—Lloyd G. Webb (1949, pp.77–78) submitted dead dove nestlings to the veterinary clinic, Ohio State University, for examination. Dr. Ingallis made the examination and gave the following report: "Clinical examination of the young doves submitted June 26, 1948, revealed lesions very suggestive of the diphtheretic [sic] type of fowl pox commonly encountered in chickens. The intramandibular space and pharynx contained a whitish raised mass of fibrinonecrotic exudate. Microscopical examination of epithelial cells from

the affected areas revealed definite intra-cytoplasmic inclusion bodies typical of those encountered in fowl pox. Unfortunately no transmission attempts were made." Webb found that approximately 8 percent of the nestling mortality in 1947 and about 22 percent of the nestling mortality in 1948 were due to pox-virus infection.

*Tennessee*—John W. Perkins, U. S. Game Agent, Memphis, reported (*in litt.*) pox infection in his captive flock of mourning doves. The outbreak began in mid-June 1959, and by June 25 the entire flock of 25 doves had succumbed. Typical pox nodules developed on the heads and wings of the doves, with the periorbital area the most frequently involved site.

An additional case of pox infection occurred in a wild mourning dove near Chattanooga.

## Transmission Studies

The relationship of mourning-dove pox to pigeon pox and other avian pox isolates has not yet been established. Material from the pox lesion on the eyelid of the dove trapped on September 17 (Locke, *et al.*, 1960) was rubbed on the conjunctiva and on the dorsum of the bill of one pigeon. A second pigeon was exposed by rubbing nodular material into an incision on the leg. Both birds were observed for a period of 1 month and neither developed pox lesions, possibly because of prior immunity or because a poor exposure site was used.

Pox viruses have been isolated from several passerine birds, and a few attempts have been made to transmit passerine pox to mourning doves. Worth (1956) was unable to infect a single mourning dove with a pox strain obtained from a slate-colored Junco (*Junco hyemalis*). He was able to infect pigeon squabs (*Columba livia*).

On February 6, 1960, a male and a female cowbird (*Molothrus ater*) exhibiting pox lesions on their feet were captured at Hanover, Pennsylvania. The birds were examined at the laboratory at the Patuxent Wildlife Research Center. The nodules were excised and rubbed onto the scarified legs of two pigeons and two mourning doves. None of these birds developed any lesions during a 2-months' observation. By the same technique, cowbird pox virus was transmitted to a junco, canaries, and young chickens, and typical pox nodules were formed.

A small trial was conducted to determine if mourning doves were susceptible to pox virus isolates of chicken origin. Two mourning doves were exposed to fowl pox isolate Ort. 101 (obtained from L. E. Hanson, College of Veterinary Medicine, University of Illinois, Urbana). The doves were exposed by rubbing a saline suspension of the virus material into scarified sites on their legs. The birds were exposed on March 31, 1960, and were observed until May 27, 1960, when they were sacrificed. No typical pox lesions developed, and both birds were normal at autopsy. Both doves were immature females that had been raised in the Patuxent Center colony and so far as was known had not previously been exposed to fowl pox.

## Discussion

Pox-virus infection in mourning doves has been found in at least 8 states on 12 separate occasions. The geographic distribution of those outbreaks, ranging from California to Maryland and Florida, suggests that pox infection may occur throughout the major part of the mourning dove's range.

The occurrence of pox infection has ranged from isolated, infected birds shot by hunters to severe, decimating epizootics, primarily among captive mourning doves. The two most severe outbreaks that have been reported occurred in captive flocks.

More studies should be conducted to determine the exact relationship of the mourning dove isolates to other pox isolates and to determine the role pox might play as a cause of mortality in mourning dove populations.

## Summary

Pox infection has occurred in mourning doves in at least 8 states on 12 separate occasions.

Unsuccessful attempts were made to transmit both fowl pox (chicken isolate) and passerine pox (cowbird isolate) to mourning doves.

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# BOOK REVIEWS

*Studies on the physiological and ecological background to the reproduction of the capercaillie (Tetrao urogallus* LIN.*).* By Vidar Marcström. Viltrevy. 1960. Vol. 2. 69pp., 24 fig. Swedish crowns 5.50 ($1.07).

This is a Ph.D thesis, presented at the University of Uppsala, Sweden.

Höglund (1955) drew attention to the fact that the poikilothermism in the chicks of *Tetrao urogallus* makes the period after the hatching critical for these birds. The chicks, which in many respects are well developed, already begin to feed independently towards the end of their first day of life. During the first weeks their thermoregulation is imperfect, and on days with unfavorable weather conditions they need additional warmth from the hen. If the environmental temperature is low for a longer period, the chicks are unable to pick up sufficient quantities of food to cover their body requirements. It seemed that they either starved or froze to death.

This problem has now been elucidated by Marcström, who has investigated the metabolism of the food reserves stored in capercaillie chicks after they are hatched. He made laboratory studies on fed and unfed chicks during the first 5–6 days of their life. Carbohydrates, proteins, and lipids were analyzed in the liver and yolk sac as well as the fat deposits of the body. Simultaneously observations were made on changes in the dry substance of body, yolk sac, and liver. The influence of weather conditions on young chicks was studied in field experiments, and was related to the significance of the body food reserves during the first weeks of life.

From the results presented in this study it appears that capercaillie chicks (127 specimens tested) hatch with considerable food reserves, consisting of yolk and subcutaneous fat, while the food substances in the liver seem to have been absorbed already during the work of hatching. Yolk resorption takes place rapidly during the time immediately after hatching and is the most important energy resource during the first 2.5 days of life. The body weight is even increased during the first day due to accumulation of body fat. Marcström shows that food intake from the environment does not normally start before the chick's second day. At unfavorable environmental temperatures the critical period for the chicks begins at this moment, when the main part of their yolk storage is used. In unfed chicks the lipids begin to break down rapidly, and the birds die at an age of 3 days.

These physiological features in small capercaillie chicks and their relations to environmental, primarily climatic conditions show how extremely thermostenotopic these birds are during their first days of life.

The author points out that the deterioration of the thermal insulation, following consumption of the body food reserves, subjects the chick to mortality factors other than starvation or freezing. The weak condition of the chicks increases the risks of infection, and their sharp and plaintive cries, uttered when they are freezing, make them more vulnerable to predators. However, it is emphasized that the role of predation in this connection is of secondary importance.

From the data presented by Marcström it is evident that the young capercaillie chicks' dependence on the weather conditions is of fundamental importance for the species' reproductive capacity. His field experiments also indicate that older chicks succumb for the same reason. Hence prolonged periods of low day temperatures may be fatal to the breeding results of a certain year-class in a certain region.

Unfortunately the role of insect food in the nutrition of young capercaillie chicks has not been elucidated. Presumably the availability of a supply of terrestrial insects is also involved during cold periods as a factor for the chicks' survival capacity. No exact data are given at what age young capercaillies cease to be poikilothermic.

In Scandinavia the populations of *T. urogallus* show strong fluctuations in number. Many explanations for these variations have been produced by various authors. Some hypotheses set the availability of food to the egg-producing hen or to the entire adult population as the determining factor for the reproductive capacity. The investigations of Marcström do not seem to confirm these theories. On the other hand, his view that meteorological conditions during the reproduction period rule the variation in number of *T. urogallus* appears to be a feature that should have been eliminated by natural selection. The explanation of the weak point in the biology of Scandinavian capercaillies may perhaps be that these populations have not yet been fully adapted to the oscillations between the Atlantic and continental types of climate which prevail in Fennoscandia. The species seems to be of Asiatic origin, and its present distribution indicates that its recent forms have evolved in Siberian areas with a mainly continental climate.

Marcström's contribution gives very important physiological and ecological details for a thorough understanding not only of tetraonid reproductive phenomena in particular but also of gallinaceous management problems in general. It focuses attention on the complexity of physiological and ecological factors involved in the reproduction biology of an important game bird.—KAI CURRY-LINDAHL, Zoological Department, Nordiska Museet and Skansen, Stockholm, Sweden.

*Grosstier und Kulturlandschaft im mitteleuropäischen Raum.* By Detlev Müller-Using. Musterschmidt-Verlag, Göttingen. 1960. 159pp. 2 photos, 20 figs. 13.80 DM.

The German title of this book may be translated as "Larger animals and the cultivated landscape in the central area of Europe." In "Grosstier" the author includes among European native or introduced mammals the following species: all of the Cervidae and *Rupicapra* occurring in Europe, *Capra hircus*, *Ovis aries*, wild boar, alpine marmot, beaver, brown hare, brown bear, lynx, wolf, fox, badger, raccoon, otter, and wildcat. He also deals with several species of birds, including some raptors, eagle owl, crane, storks, heron, cormorant, swans, geese, great bustard, and the Tetraoninae, but excludes pheasant and partridge. According to the title of the book the area covered is central Europe, but for some species the author also considers the situation in Scandinavia. He bases his material on available regional statistics of kills from Germany, Austria, Switzerland, and Luxembourg, as well as on the literature and in some cases on Scandinavian game figures. On the basis of this information he interprets the game fluctuations in number during the last hundred years.

The conclusions are that "of the 18 treated European mammals" (there are in fact 19) 11 species have increased considerably. Among these are all Cervidae (except *Sika nippon* and *Dama dama*), *Rupicapra*, *Capra*, *Ovis*, wild boar, alpine marmot, fox, and badger. Two species, fallow deer and beaver, increase or decrease locally. Three have decreased in number as well as in range, but are now locally increasing again; they are bear, lynx, and wildcat. Two species, wolf and otter, are characterized as exterminated in large areas and on the way to total extermination within their European ranges. Finally, two species, said to have enriched the European fauna by introduction, are sika deer and raccoon.

One species, discussed by the author in the main text, seems to have been completely forgotten in his conclusions on faunal balance. This species is the brown hare, which in reality also belongs to those mammals which have increased considerably.

Among the birds, Müller-Using mentions in his balance that six (unnamed) raptors have increased with certainty, but the reviewer has failed to find out in the main text which they are. From the data presented, there seems to be evidence for an increase of only four birds of prey: two kites (*Milvus milvus* and *M. migrans*) and two eagles (*Aquila chrysaëtos* and *Haliaeetus albicilla*). The mute swan is also said to belong to the increasing species, which is certainly true; in addition it is possible that the raven and the heron are increasing, according to the author.

Many surprising features in this book are related not only to the conclusions and the material presented but also to the selection of species. It is difficult to understand why mammals having a wide distribution in central Europe, such as the rabbit, the muskrat, and a number of the Mustelidae, have not been treated at all although a species like the introduced raccoon is discussed (even if the European history of the latter is particularly interesting). And why exclude the mountain hare but include the alpine marmot, two species that have almost exactly the same distribution in central Europe? It cannot be the size of the animals that has always determined the author's choice, because several of the species excluded are larger than those which are included. One may say the same about the birds. Perhaps the answer is a lack of statistics on certain species, but the European literature on distributional changes is extensive.

More serious, however, is the inaccurate way of treating the species that are discussed. It is, for example, astonishing indeed when the author states that *Rangifer tarandus* belongs to a species that has increased in Europe. His assumption relies on data from Fennoscandia, but he does not seem to know that wild reindeer became exterminated in Sweden and Finland during the last century. It has survived in Norway and there has recently increased in number, a fact which causes the author to speak of an increase in Europe during the last hundred years! The chapter on *Capreolus* is based on statistics, while the literature with discussions about the recent expansion of this species is entirely neglected, which is unfortunate for the author.

The reviewer does not share Müller-Using's opinion that the otter is on the way to extermination in Europe. It is a mammal that lives in secret, easily adapts itself to new habitats, and maintains its number in many European areas astonishingly well. The statement of a "strong increase" of the white-tailed eagle is partially based on Swedish data, which apparently have been completely misunderstood.

The author's "faunal balance" and his conclusive discussion of the fluctuations in number during the last hundred years in Europe are in many ways misleading and even erroneous. No true comparisons of fluctuations in numbers of different mammals and birds can be made appropriately, when the basic material used in this book varies so much in quality or is interpreted incorrectly, and when the author does not even attempt to distinguish between long-term and short-term variations or to put these oscillations into relation to various ecological factors. For instance, when he states that the four birds of prey mentioned above have increased, this is a remarkable declaration. In fact, few species have declined so much during the last century in Europe as kites and eagles, but the fact that they quite recently have increased locally to a degree far from their former population levels, leads him to include these birds in the category of animals which have expanded during the last hundred years.

The bibliography of 11 pages consists almost

entirely of German papers, and shows that the author has not consulted certain important works which might have led him to a better understanding of the topic he has tried to investigate.—KAI CURRY-LINDAHL, Zoological Department, Nordiska Museet and Skansen, Stockholm, Sweden.

*Methods of Vegetation Study.* By Edwin A. Phillips. Henry Holt and Co., New York. 1959. xvi + 107pp. $2.95.

*Manual of Vegetation Analysis.* By Stanley A. Cain and G. M. De Oliveira Castro. Harper and Brothers, New York. 1959. xvii + 325pp. $7.50.

Wildlife biologists typically spend as much time on field analysis of habitats as on study of animal populations. Habitat analysis inevitably requires measurement of vegetation, and the wildlife biologist's training often does not equip him adequately in the techniques of vegetation measurement. The titles of two recent books indicate that they may help in filling this gap in the education of the working wildlife biologist.

Phillips' book is primarily a set of field exercises for an introductory course in plant ecology. The instructions for a variety of methods, some of them unfamiliar, make the book of value even to the experienced wildlife biologist. It is small in size and bound in flexible but durable plastic, so that it can easily be carried in the field.

Most of the common techniques of plant ecology are described. Among the subjects covered are physiognomic description of vegetation by Dansereau's "lollipop" diagrams; frequency and density measurements; some of the currently popular plotless methods such as the Bitterlich and the random pairs; line transects; and many others. The last half of the book deals with the synthesis of data from different stands and the comparison of the vegetation of different areas. The Clementsian system is covered in three pages, Curtis' continuum concept in four, and the Braun–Blanquet phytosociological school in three. Other sections are devoted to community coefficients, to contiguous quadrat analysis, and to the use of scatter diagrams in vegetation classification, among other subjects.

Obviously, a book covering such a variety of topics in such a small space cannot be very detailed or very critical. Techniques, but not the reasons for them, are described. There is little effort to weigh the usefulness or the validity of the methods presented. These lacks limit the value of the book to the practicing wildlife biologist. Still, this little book presents a valuable outline of a good many important ecological methods.

Cain and Castro's volume is far more ambitious in scope and format. It is primarily concerned with concepts of vegetation as they have been developed by botanists, and with the theoretical and analytical bases of these concepts. It deals only incidentally with field techniques for description and analysis. The book is an outgrowth of a year spent by the senior author in tropical America, where he worked with the Brazilian ecologist Dr. Castro. Examples and illustrations are largely drawn from the tropical rain forest. This may limit its usefulness to some provincial biologists, but the treatment of this little-known region broadens the book's general interest.

The discussion begins with a definition of a community as a sociological unit occupying a territory and having a characteristic composition and structure. Within this broad definition, concepts of community structure are considered and the tropical rain forest is used as an example of the many ways in which plant species can be organized into integrated vegetation units recognizable over wide areas.

Number of individuals, their patterns on the ground and in vertical stratification, and dominance or ground coverage are the principal structural features of vegetation. Many methods have been devised for evaluating each of these, and the authors discuss the principles and objectives of most of the techniques more briefly described by Phillips. Their discussion of pattern analysis is centered around frequency methods, and does not consider some of the more recent procedures based on distance measurements or contiguous quadrats. Finally, the synthesis of many separate vegetation characteristics is used to arrive at an objective description of plant communities.

The field biologist seeking a "cookbook" manual of vegetation techniques will not find it in Cain and Castro's book. For the man with a little training in plant ecology, it is a stimulating guide to some of the newer ideas in community classification and description.

A disturbing feature of both books is their lack of emphasis on vegetation dynamics and community productivity. Both give limited attention to plant succession and to seasonal periodicity, but for the most part they consider plant communities as static entities. Applied biologists, in wildlife management, forestry, or range management, are primarily concerned with production of plant material and its utilization by all the organisms in the community. Methods and concepts for measurement of productivity are still being developed, but they have a distinct place in a treatment of vegetation analysis. It is especially unfortunate that Phillips' workbook so largely ignores this topic, for many undergraduate students may find their only introduction to ecological field methods in the pages of this text.—CHARLES F. COOPER, Watershed Technology Research Branch, Soil and Water Conservation Research Division, Agricultural Research Service, U.S.D.A., Boise, Idaho.

*An Introduction to American Forestry.* By Shirley Walter Allen and Grant William Sharpe. McGraw–Hill Book Company, Inc., New York. Third edition, 1960. viii + 466 pp. $7.95.

In 1937, when I was a senior in forestry at the University of Michigan, it was rumored that Professor Shirley Allen was writing a book "all about forestry." As it turned out, this piece of gossip was true. The following year the first edition of *An Introduction to American Forestry* came off the press. The book was described by the publisher as a general text for beginning classes, and the author "cherished the hope" that it would be "useful outside as well as inside the classroom," and would give forestry "a wider circle of acquaintances." During World War II, I read the book from cover to cover, and found that it was indeed "useful outside as well as inside the classroom." That reading constituted a review, a summing up, and a filling in of my forestry education.

When the 1950 edition of this book was published, I borrowed a copy, compared it with the 1938 edition, and decided not to add it to my personal library. Revisions were quite moderate.

It is, however, quite a different story with the third edition, the subject of this review. In this edition, Professor Allen, now retired, is joined by G. W. Sharpe, Assistant Professor of Forestry at the University of Michigan. In redoing the book, the authors have retained the same 21 chapter titles, and the same number of figures (124), but they have completely rewritten 9 chapters, considerably revised 4, slightly revised 8, and have used almost all new figures.

Beginning with a discussion of the relation of men and forests from prehistory, the authors move in staccato rhythms to the story of forests in the building of America, where forests are located, what they produce, and what they are. Next, quite appropriately, three chapters are devoted to an explanation of "the building up, setting in order, and keeping in order a forest business." This trinity of chapters is followed by another unit of three chapters which introduces the reader to the problems of defending the forest from fire, insects, disease, and the elements. Then, spanning 53 pages at the middle of the book, there are two chapters that stand out in bold contrast, because the first, on "Measuring the Forest," is strikingly modern, and the second, on "Harvesting the Forest Crop," is strikingly out of date. But at this point, the authors move on, quite abruptly, to more general topics, and explain how forest products are made ready for the consumer, "the beneficial influences and services from the forest," forest policy in the United States, the practice of forestry by the federal government, states, communities, and private owners, and close with a discussion of forestry education, positions in forestry, and national planning in forestry.

The different topics follow one another quite logically, and together present a comprehensive view of forestry. The balanced way in which the authors deal with most subjects makes it difficult to give a good sample in brief quotations. But let me try to do so.

On the forest: "A forest is a complex community of organisms. It is more than just trees, because it includes shrubs and smaller plants, animals of many kinds, and soil and water. The forest is located both on and in the soil. It might include mountains, canyons, streams, and even small open places. . . . As a community, the forest is a scene of struggle, with those individuals best able to adapt themselves to their environment reaching the highest development. . . . What is true in the trials of single trees or groups in a forest is true in another sense for forests as a whole and for types within a forest."

On the selection cutting system: "A surgical operation on an all-aged forest in which trees reaching maturity in age or size are selected for cutting is called the *selection system*. . . . Nature does something like this, but the natural process takes longer and the end result is not as satisfactory. Her cuttings are deaths from old age or natural phenomena."

On forestry as a public policy: "Public policy in a democracy is, theoretically, the will of the people. When the people want forests perpetuated and managed for beneficial use, the practice of forestry will be accepted on an even broader scale than is assumed by the present public policy. Owners will probably have to charge more for forest products, and the public will have to be sufficiently interested to pay more."

On wildlife management: "This industry (i.e., the income from hunting licenses and from sale of guns, fishing tackle, etc.) depends upon the forester to manage his forest area on a principle of multiple use. Wildlife management courses should be a part of every forester's training in order to instill in him an appreciation for the problems of the wildlife manager. The latter, whose training should closely parallel that of a forester, must also be familiar with the problems that confront the forester."

If there is a major lack in the book, it is in its failure to deal adequately with one of the most important single elements in the management of a forest. This is in "harvesting the forest crop." Here the authors fail to point up the great changes in the logging industry since World War II. For example, the impression is given that most loggers live in camps. But, actually, logging camps have become rare. The majority of loggers live in town with their families, and go to and from work in automobiles. Then, too, there is barely a hint of the fantastic changes in logging equipment which have taken place. Probably nothing has affected the forest and its management more than the development of equipment for building roads and harvesting the timber.

In spite of this deficiency I rate the book highly, and feel that any person whose vocation or avoca-

tion takes him into the forest should have a copy of the third edition of *An Introduction to American Forestry* in his library, and should study it. And I hope "a wider circle of acquaintances" will also read the book. In truth, it is the best book of its kind for all classes of readers.—C. I. MILLER, Department of Forestry and Conservation, Purdue University, Lafayette, Indiana.

*Introduction à L'Ecologie des Ongules du Parc National Albert.* François Bourlière and Jacques Verschuren. Exploration du Parc National Albert: Mission F. Bourlière and J. Verschuren (1957–1959), Institut des Parcs Nationaux du Congo Belge, Brussels. 1960. 2 vols., 158pp., 52 plates, and color frontispiece.

The magnificent big game herds which exist in favored portions of the eastern Congo have an uncertain future. Like those in the diminishing wildlife areas of other parts of Africa, their fate is obscure as the Congo moves from colonial to independent status. Whether the considerable economic and scientific values of the wildlife resource will be recognized by the new governments and, even if so, whether these governments can effectively influence their citizenry to cooperate in wildlife management and preservation are questions which only time will answer.

To place on record the ecological characteristics of the remarkable African animal communities before they disappear or are altered radically is a challenge that only in very recent years has begun to be met. The authors of "The Ecology of the Ungulates of King Albert National Park" have gone far in providing important records of the eastern Congo's large-mammal fauna and its environment. Their work is the result primarily of observations made between mid-1957 through 1959 but it derives a major value from the records of the Institut des Parcs Nationaux du Congo Belge, which date back about 30 years. Professor François Bourlière is a member of the Faculty of Medicine, Paris, while Jacques Verschuren is a longtime Institut biologist of the Parc Albert. Volume I is the written report, while Volume II is a collection of fine photographs, excellently reproduced, and documenting the textual material. There is a five-page English summary and the literature cited is itself an important bibliographic aid to workers in African vertebrate ecology. This is the most detailed ecological study of an African mammal population yet reported.

Of the considerable data assembled on the 22 recorded species of Parc Albert ungulates, that on population density and structure is especially valuable. Censuses on 826 sq. km. of open plains were made by placing markers along parallel lines 1 km. apart and having African game guards under European supervision walk abreast along the marked routes. Each man counted the animals seen within 500 m. on each side of his line. Counts were also made in four line transects in definite vegetation types. Odd areas were covered by car. On 600 sq. km., an average was determined of 34.9 animals or 24,406 kg. biomass per square kilometer.

Total biomass computations in themselves, of course, do not disclose the sustained productivity or yield characteristics of the biotic community. Stability of biomass in terms of habitat carrying capacity and optimum rates of herd increase in numbers and biomass are among the factors which also must be considered.

On the subject of carrying capacity, the authors defer judgment until further studies are completed, but apparently they do not feel that the range is extensively overgrazed, as American biologists have found in some Kenya and Uganda national parks. During the last 30 years, however, the authors advise that Parc Albert records indicate "spectacular" increases in elephants (due to both increased rates of immigration and survival) and buffalo. Hippopotamus numbers, they say, "appear to be far more stable," yet there has been a 43.7 percent increase since 1931. Topis and kobs decreased after 1931 but in recent years again have become more numerous. Three areas photographed about 25 years ago and again in 1959 comprise a record of vegetative change which is unusual in African studies. They show scrub invasions of grasslands near a hippo-inhabited river and on a steep hillside. But reduced amounts of woody vegetation are evident on another plain, apparently now heavily grazed.

In my experience on the nearby Uganda plains, shrub invasion occurs as a result of overgrazing, erosion, and consequent limitation of fire. It involves mostly woody plants which are not preferred foods of elephants and other browsers. The first two pairs of Congo photographs give every evidence of shrub invasion due to overgrazing. Shrub reduction, on the other hand, may occur either as a result of hot grass fires or of heavy browsing by elephants where their favorite foods are concentrated, or both. Further knowledge of the plant-species composition and of the fire- and animal-history of these areas would be most useful in interpreting the third pair of before-and-after pictures.

Valuable data have been assembled by the authors on the sex composition and average size of herds of the more numerous species. New age determination criteria and age structure statistics are also provided for some species. Unfortunately, however, age criteria are not well established for many other species and the annual yields of which game herds might be capable cannot be determined accurately. Yet Bourlière and Verschuren have assembled a great deal of useful data on the subject and give interesting information on percentages of females (three times as abundant as males among the adults of several species) and of adults (mostly 55 percent to 73 percent) in the various populations.

Breeding may occur in any month of the year for all species. Natality rates were computed which ranged from 9.2 percent of the total population for elephants to 31.9 percent for some topi herds.

Predation was found generally to be a negligible mortality factor. Diseases were occasionally significant for buffalos and hippos. Competition for food "does not appear to play an important role among herbivores in the Park." Toxic gases (mainly $CO_2$) killed a number of animals in volcanic areas. Correlative information on the area's climate, soils, topography, vegetation types, and animal habitats is copious.

This two-volume work is thoughtfully and appropriately dedicated to the eminent Professor Victor Van Straelen on the 25th anniversary of his directorship of the Institut des Parcs Nationaux du Congo Belge. As American biologists facing less complicated problems, perhaps it would be appropriate for us to take this opportunity to join in expressing appreciation to our fellow dedicated conservationists overseas who have struggled amid difficulties and hardships to preserve at least a few of the remaining primitive parts of the world.

As this review is being written, there is evidence that the fine work of the Belgian parks administration may yet survive the current Congo disorders. A letter (Oryx, 5(6):365–366, 1960) by the Honorable R. L. P. Dreschfield, Chairman of Trustees, Uganda National Parks, and the capable sponsor of the Fulbright wildlife program in that country, states that the Parc Albert, despite some poaching in the early days of independence, is still in a preserved status, with every effort being made by President J. Miruho of Kivu Province to maintain its recognized scientific, touristic, and economic values. Chairman Dreschfield advises further that, as of September 27, 1960, Biologist Verschuren was still on the park staff, continuing his efforts in behalf of an enlightened attitude toward what must be Africa's most unique heritage, its wildlife populations.—GEORGE A. PETRIDES, Departments of Fisheries and Wildlife, and Zoology, Michigan State University, East Lansing, Michigan.

*Environmental Conservation.* By Raymond F. Dasmann. John Wiley and Sons, Inc., New York. 1959. x + 307pp., 153 illus. $6.50.

I should like to preface this discussion with the observation that, despite some minor or picayune objections which may be posed, *Environmental Conservation* is an admirably conceived and skillfully executed addition to the conservation repertoire. The first of 12 chapters presents the usual definitions and concepts. This is no usual introductory chapter, however, for it shortly makes the reader conversant with fundamentals such as communities and ecosystems, succession and chemical cycles, pyramids and food chains, and the principle of sustained yield, all of which are requisite to a comprehension of what is to follow. Particularly gratifying is the inclusion of a brief explanation of the significance of the second law of thermodynamics, a basic concept all too frequently omitted even in "comprehensive" wildlife curricula. Chapter 2 acquaints the reader with the major biotic regions of the world and their significance to man. The 35 pages in chapter 3 review "Man's Record on the Earth" from the assumed establishment of *Homo sapiens* through the current environmental mismanagement perpetrated and perpetuated by the benighted Caucasian and all his teeming cohorts.

The subsequent six chapters are almost described by their titles, viz., "Agricultural Lands and Soil Conservation," "Civilization and Water," "Forests and Man," "Livestock on the Range," "Land and Wild Animal Life," and "Water and Fisheries." Most of these chapters follow a generalized pattern involving historical aspects, foreign and domestic conditions, and discussions of conservation practices. The conventional treatment is modified, however, in that the interrelations of these resources are repeatedly pointed up and, with the understandable exception of the discussion on marine fisheries, each chapter closes with a special section devoted to emphasizing the "environmental approach" and the futility of single resource management (pp. 114, 145, 174, 207, 229). This theme receives further elaboration in a short but cogent chapter of its own, "The Conservation of Environments," in which the artificiality of the traditional separation of resources is graphically depicted. The idealistic pictures Dasmann paints of cities merging gracefully and amiably with surrounding suburban areas and farmland may seem to suggest the utopianist, particularly when he points out that this will ultimately require a complete tearing down and rebuilding for most cities. However, the suggestion that, by providing a local woodsy smell for the hordes of city cave dwellers, we might well remove much of the current, suffocating, dilettante pressure from our national parks and wilderness areas is a thought not to be lightly dismissed (p. 262). A well-chosen quotation from Leopold's *Sand County Almanac* emphasizes the need for public education if conservation is to become a reality.

Up to this point Dasmann has produced a highly commendable work, delineating the history and the nature of our resource problems. Had he stopped here we would have had another good book on conservation, noteworthy for the emphasis on *legitimate* "multiple purpose" planning. But he did not. In the 27 pages devoted to chapters 11 and 12, titled "The Problem of Population" and "The Outlook," he has pinpointed and documented the crux of the dilemma upon the proverbial horns of which modern man is impaled. Coolly, factually, and concisely, any but the most obtuse or pragmatic reader is brought face to face

with the conclusions that all change is not progress, all growth is not good, and all the world will not suffice to provide man with anything but a sterilized physical, mental, and esthetic existence unless the present population trends are rectified. This, despite the fact that Dasmann seldom forces the thought down one's throat. In fact, he conscientiously presents the optimist's arguments. Quotations from the writings of Marston Bates, Jacquetta Hawkes, Harrison Brown, and Lewis Mumford help to delineate the two alternatives. Obviously, the question boils down to a sense of values. Just as obviously, although there is still time for a decision, procrastination narrows the choice. The optimists and the people writing the current rules for "progress" will not like the book. It tends to discourage procrastination.

The handy size, decorative covers, and generally well-chosen illustrations make this an attractive book. "Much" instead of "must" (p. 7), the inconsistent spelling of podsol (pp. 30, 43, 93, index), and an undated reference (p. 283) are among the rare editorial oversights noted. If cost saving figured in the inclusion of illustration page references in the general index (which makes some of them hard to relocate), it would have been better served by deleting the innumerable repetitions of uncited references in different chapters. The method of handling references was, for this reviewer, the least satisfactory part of the book. With 14 references to one multiple-author book in one chapter it seems superfluous to cite the book a fifteenth time under the editor's name. This same book is listed 41 times in various chapters, often without any specific reference thereto. A cursory examination reveals 55 duplications among 235 references listed, many of them not cited in the text. It is also disconcerting to be referred to 300- and 400-page books without specific page references. One wonders why Odum's ecology text is cited as a reference for Chapman's concepts of biotic potential and environmental resistance (p. 219), or why the same book plus Black's *Biological Conservation* are the selected references in a discussion of eutrophic lakes (p. 238). Curiosity may be aroused by the selection of deer as the species to illustrate a "typical" sigmoid curve leveling off at the carrying capacity (p. 219), and the coupling of "prehuman ancestors" with "tools and the use of fire" is at least questionable (p. 50). Some readers will admire the author's restraint in handling controversial issues. Conservation is properly an ethic and a philosophy, not a dogma. As such, many find the emotional impact of much contemporary literature on the subject objectionable. Nevertheless, this is meaty fare. Dasmann's typewriter is not only very articulate but extremely well tempered. Occasional poignant statements notwithstanding, it habitually writes in ink: there is seldom any blood on the page.

The preface indicates that this text was prepared for use in a one-semester course at the lower division college level. The author intimates that only after waiting many years for someone else to write such a book "from a biological point of view" (i.e., considering conservation problems from the human population viewpoint), has he ventured the task himself. If any further justification is required for "another book on conservation," the emphasis this one places on the necessity of integrated resource management justifies its existence. Despite (or because of) the current prevalence of the provincials who subscribe to the bigotry that significant science does not exist above the molecular—or at most, cellular—level, this reviewer looks forward to the day when a general conservation course will be listed among our college requirements for graduation. The awareness of natural resource values that such a course should instill is as vital to citizenship as are chemistry, mathematics, and the proper use of the English language. This book would serve admirably as a text in such a course.—ERNEST E. PROVOST, School of Forestry, University of Georgia, Athens, Georgia.

*The Canvasback on a Prairie Marsh.* Second edition. By H. Albert Hochbaum. Stackpole Co., Harrisburg, Pa. 1959. 207 pp. $4.50.

The first edition of this classic waterfowl study appeared in 1944. It should come as good news to many people that with the publishing of this second edition the book is once again readily available.

The second edition is an exact reprint of the original with the exception of an addenda appendix of four and one-half pages and a reference list of 15 titles covering the addenda material. The new appendix treats each chapter separately, and relates more recent findings and ideas to the original theme of the book. While the new material does not change the original greatly, the modifications based on recent findings in both renesting behavior and the application of the territory concept to waterfowl are significant.—OSCAR W. JOHNSON, Department of Zoology, Washington State University, Pullman, Washington.

*Marine Biology.* Transactions of the Institute of Oceanology. Vol XX. Edited by B. N. Nikitin, USSR Academy of Sciences Press, Moscow. 1957. 302pp. Published by the American Institute of Biological Sciences, Washington 6, D. C. $10.00. $7.50 to AIBS Members.

This volume was published under a peculiar, dichotomous aegis, which is more than a little confusing, and I have the impression that this is the result of an attempt to make more of the book for purposes of advertising and sale than it deserves. In the first place, this is not a text on marine biology. It is a translation of one volume of a Russian journal published in 1957. It is not

customary to review issues of journals, but this is a special case. Strangely enough there is no statement that the volume is a translation, but one of the tables has a footnote by the "Translator." Undoubtedly, the anonymous editors of the English version failed to delete the word in proof reading. It is highly doubtful that the English version was edited by Professor B. N. Nikitin, or that it was printed by the USSR Academy of Sciences for the AIBS, as the title page would lead the reader to believe.

I am told that this is a good translation. There has been some quibbling over the complete transliteration of the Cyrillic alphabet, but there usually is. All in all, the translators seem to have done a good job. In any case the text is in clear, readable English with few exotic expressions. However, I was struck by one author's use of the term "fodder organisms" for food organisms—not a bad term.

This volume, like most journals, is a reference work and was not designed to be "read." Of 13 papers, one is taxonomic (hyperiid amphipods), three papers concern the general plankton, and five concern the benthos or bottom fauna. There are four papers of the classical fisheries type (age, growth, distribution, etc.). The viewpoint of broad zoogeographic and ecological principles prevails in most of these papers. This is shown by some of the titles, paraphrased here, viz. euryhalinity of Black Sea benthos and the possibility of settlement in the Sea of Azov, bottom fauna groupings of the north Okhotsk Sea, food interrelations of dominant species in benthic biocenoses, and spatial interrelationships of zoo— and phytoplankton.

The broad viewpoint of the Russian authors makes the volume of particular interest to the marine biologist and fishery worker. The work should be in all marine station and many university libraries, but I would not recommend its purchase by the younger individual worker. Instead, it should be recommended to the librarian. She will be puzzled as to just how to file it, but presumably it will be made available somehow.

Many American biologists feel the press of time and age too strongly to undertake the acquisition of a reading knowledge of Russian. For that reason I hope that "Marine Biology" is not an abortive effort of the American Institute of Biological Sciences, and that publications of translations of Transactions of the Institute of Oceanology will be continued. If so, I respectfully recommend that the AIBS cut the attempts at bedazzlement and state clearly what the proposition is. My own laboratory would be a willing subscriber to the series.—GORDON GUNTER, Field Laboratory, Texas Game and Fish Commission, Seabrook, Texas.

*The Birds.* Oskar Heinroth and Katharina Heinroth. University of Ann Arbor Press, Ann Arbor, Michigan and Ambassador Books Ltd., Toronto, Canada. 1958. 181pp., 91 figs. $5.00.

This is a translation of Oskar Heinroth's well-known work "Aus dem Leben der Vögel," as revised by his widow. It is distinguished by the clear concise presentation of bird biology with emphasis on the structural adaptations and behavior of birds. Written in a simple style, the book will give the beginning ornithologist an excellent framework of knowledge on which to observe and understand structural features and behavior patterns; the experienced student will glean a better understanding of the significance of the structure and behavior of birds. The ecologist and wildlife conservationist may be disappointed by the absence of discussions on geographic distribution, ecology, and population dynamics. No bibliography is given to document the facts presented.

This book presents the conclusions reached by two very capable ornithologists who have carefully and exhaustively studied living birds both in captivity and in the wild. The reviewer knows of no work that can give the beginner such a firm foundation in avian biology. It might well be required reading for anyone working on problems involving bird behavior and structural adaptations. The illustrations in this edition are exceptionally clear and effective. The translation by Michael Cullen is idiomatic and easy reading.—F. M. BAUMGARTNER, Department of Zoology, Oklahoma State University, Stillwater, Oklahoma.

*Arctic Wild.* By Lois Crisler. Harper & Brothers, New York. 1958. 301pp., illus. $4.95.

For 18 months, Herb and Lois Crisler lived in a remote part of the Alaskan Arctic. Herb's magnificant photographs of herds of caribou, packs of wolves, wolverines, and other animals were the backbone of the Disney film "White Wilderness." In "Arctic Wild," Lois records, in highly readable fashion, their personal experiences and their observations of behavior of wolves, of caribou, and other Arctic wildlife. In spite of an occasional lapse into anthropocentric interpretation, the behavioral descriptions are worthy of attention by biologists. Indeed, few of us will ever have the opportunity personally to observe these wilderness creatures of the Arctic as intensively as the Crislers. This vicarious opportunity is well worth taking.—JOHN L. BUCKLEY, U.S. Fish and Wildlife Service, Laurel, Maryland.

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